UFISINAN I MAGA'HÅGA
OFFICE OF THE GOVERNOR

LOURDES A. LEON GUERRERO
MAGA'HÅGA • GOVERNOR

JOSHUA F. TENORIO
SIGUNDO MAGA'LÅHI • LIEUTENANT GOVERNOR

HAND DELIVERED

July 26, 2019

Speaker Tina Rose Muña Barnes
JUL 26 2019
Time 4:32 ( )AM ( )PM
Received By: Matt

HONORABLE TINA MUÑA BARNES
Speaker
I Mina'trentai Singko Na Liheslaturan Guåhan
Guam Congress Building
Hagåtña, Guam 96910

Re: Executive Order 2019-18

Dear Madam Speaker:

Pursuant to Public Law 34-16, transmitted herewith is Executive Order 2019-18:

> **Executive Order 2019-18 Relative To Adopting And Promulgating The Updated 2019 Guam Hazard Mitigation Plan.**

Accompanying this Executive Order is a compact disk (CD) that contains the 2019 Hazard Mitigation Plan (324 pages).

If you have any questions or concerns, please do not hesitate to contact Legal Office at 475-9475 or via email.

Senseremente,

SOPHIA SANTOS DIAZ
Legal Counsel

Enclosure: Executive Order No. 2019-18

cc: *Maga'hågan Guåhan* (via email)
Sigundo Maga'låhi (via email)
Compiler of Laws (via email)
Central Files (via email)

ISLAND OF GUAM
OFFICE OF THE GOVERNOR
HAGÅTÑA, GUAM 96932
U.S.A.

Executive Order No. 2019 – 18

RELATIVE TO ADOPTING AND PROMULGATING THE UPDATED 2019 GUAM HAZARD MITIGATION PLAN

WHEREAS, the island of Guam is under regular threat of natural, human-made and technological disasters responsible for causing mass casualties, injuries, losses of real property, and damages to our island's environment; and

WHEREAS, while the occurrence of destructive forces of nature cannot be eliminated or altered, hazard mitigation measures and responsible preparedness planning can be taken to reduce their impact to our island community; and

WHEREAS, the well-being and safety of our island residents, its environment and property are the primary concern of this administration, more specifically the Offices of Guam Homeland Security and Civil Defense, which collaborate with other Government of Guam, federal, military and private emergency response organizations to protect our people from these hazards and disaster threats; and

WHEREAS, in Executive Order 2014-11, the Government of Guam created and adopted the 2014 Guam Hazard Mitigation Plan ("Guam HMP"), which was a comprehensive strategy that focused on mitigating and reducing Guam's exposure and vulnerability to natural and human-made disasters; and

WHEREAS, due to its geographic isolation, Guam relies on both technical and logistical assistance from federal and private sector partners during response to and recovery operations for catastrophic events, making collaborative pre-planning efforts and partnerships between all parties a critical necessity; and

WHEREAS, under the federal Disaster Mitigation Act of 2000 and its regulations, all state hazard mitigation plans are required to be updated and re-approved by the Federal Emergency Management Agency ("FEMA") every five years; and

WHEREAS, the Government of Guam has updated the 2014 Guam HMP to create the 2019 Guam Hazard Mitigation Plan ("2019 Guam HMP"); and

WHEREAS, the 2019 Guam HMP demonstrates Guam's continued commitment to reducing the risk of losses from natural and human-made hazards and serves as a strategic planning guide for Guam's decision-makers as they commit resources to reduce the effects of these hazards; and

WHEREAS, the 2019 Guam HMP describes Guam's procedures for identifying hazards, risks, and vulnerabilities, and it also identifies and prioritizes mitigation actions, encourages the ongoing development and effective implementation of Guam's specific mitigation strategies, and provides technical support for these efforts; and

ISLAND OF GUAM
OFFICE OF THE GOVERNOR
HAGÅTÑA, GUAM 96932
U.S.A.

NOW, THEREFORE, I, JOSHUA F. TENORIO, *Åkto Maga'låhen Guåhan*, Acting Governor of Guam, in full consultation and coordination with **LOURDES A. LEON GUERRERO**, *Maga'hågan Guåhan*, Governor of Guam, and by virtue of the authority vested in me by the Organic Act of Guam, as amended, and the laws of Guam, do hereby promulgate and adopt the 2019 Guam Hazard Mitigation Plan to be effective as of the date set forth herein; and further ORDER the following:

1. This Executive Order and the attached 2019 Guam Hazard Mitigation Plan shall supersede Executive Order No. 2014-11 and the 2014 Guam Hazard Mitigation Plan; and

2. All other mitigation activities by the appropriate entities and government agencies shall be in accordance with the Mitigation Strategy developed and presented within the 2019 Guam HMP; and

3. Any further updates to the 2019 Guam HMP shall be coordinated via the established Plan Maintenance Process through the Guam Hazard Mitigation Officer (State Hazard Mitigation Officer) with the Guam Homeland Security/Office of Civil Defense and the Guam Hazard Mitigation Advisory Committee; and

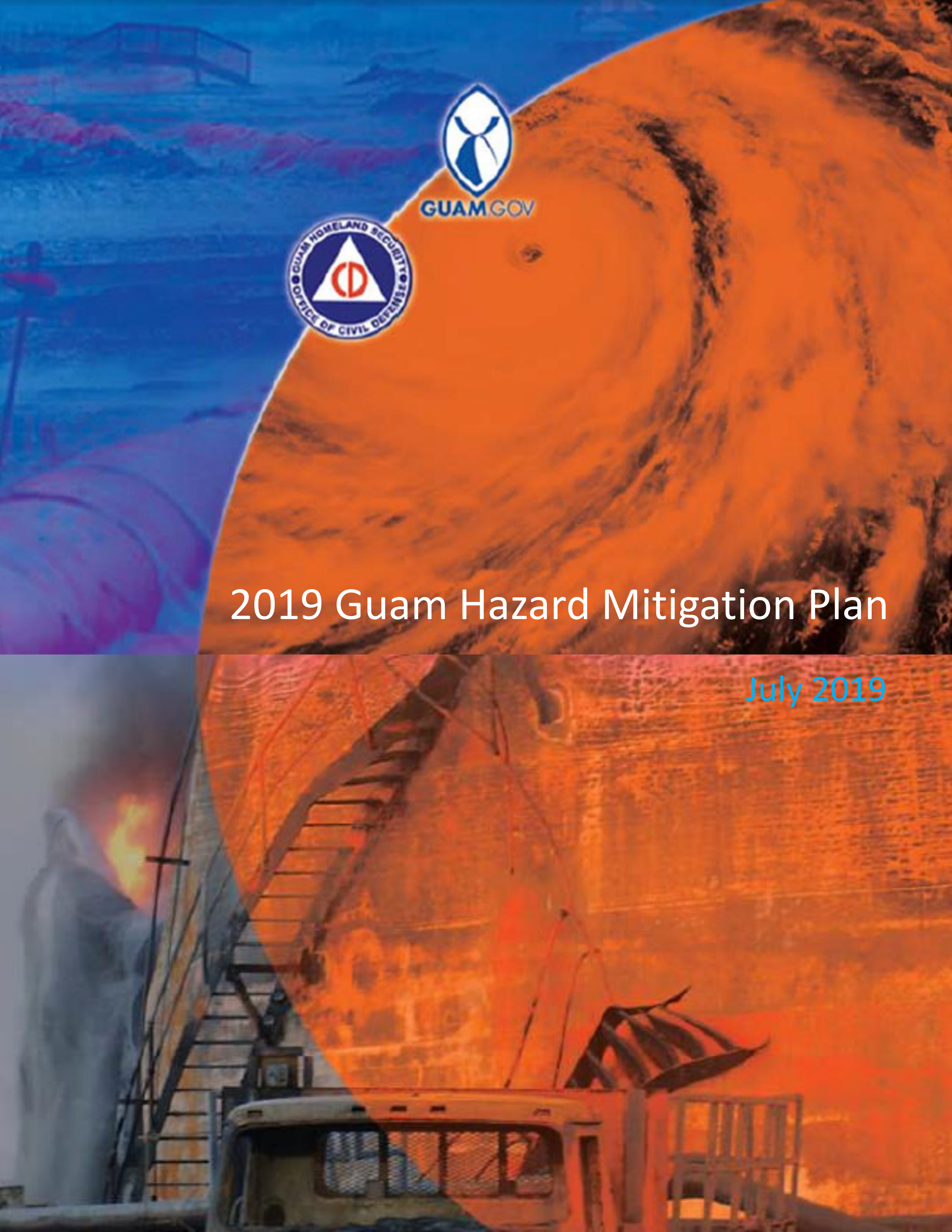
4. The 2019 Guam HMP also supersedes any previous Guam Hazard Mitigation Plans purporting to address disaster recovery or rescue matters and shall be included as one of the appendices of the Guam Comprehensive Emergency Management Plan.

Signed and Promulgated at *Hagåtña*, Guam, this 26th day of July, 2019.

JOSHUA F. TENORIO
Åkto Maga'låhen Guåhan
Acting Governor of Guam

Attested by:

AMANDA S. SHELTON
Åkto Sigundo Maga'hågan Guåhan
Acting Lieutenant Governor of Guam



2019 Guam Hazard Mitigation Plan

July 2019

2019 GUAM HAZARD MITIGATION PLAN

Guam Homeland Security/Office of Civil Defense
221B Chalan Palasyo
Agana Heights, Guam 96910

Pre-Final Version B
July 13, 2019

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Tables

Graphs

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Acronyms and Abbreviations

°F	degrees Fahrenheit
ANA	Administration for Native Americans
APHIS	Animal and Plant Health Inspection Service
ASCE	American Society of Civil Engineers
BBMR	Bureau of Budget and Management Research
BSP	Bureau of Statistics and Plans
BZPP	Buffer Zone Protection Program
CDBG	Community Development Block Grant (Program)
CDC	Centers for Disease Control and Prevention
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
C.F.R.	Code of Federal Regulations
CIP	Capital Improvement Project
CNMI	Commonwealth of the Northern Mariana Islands
CRB	coconut rhinoceros beetle
CZMP	Coastal Zone Management Program
DFIRM	Digital Flood Insurance Rate Map
DLM	Guam Department of Land Management
DMA 2000	Disaster Mitigation Act of 2000
DPHSS	Guam Department of Public Health and Social Services
DPW	Guam Department of Public Works
EFMUTS	Essential Facilities, Major Utilities, and Transportation Systems
ENSO	El Niño–Southern Oscillation
EPA	Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-To-Know Act
ER	Emergency Relief (Program)
ERP	Emergency Response Plan
ESF	Emergency Support Function
ESG	Emergency Shelter Grant
FAA	Federal Aviation Administration
FEMA	Federal Emergency Management Agency

FIRM	Flood Insurance Rate Map
FMA	Flood Mitigation Assistance (Program)
FY	fiscal year
g	the vertical acceleration force due to gravity
GAR	Governor’s Authorized Representative
GBS	General Building Stock
GEDA	Guam Economic Development Authority
GEPA	Guam Environmental Protection Agency
GHMGP	Guam Hazard Mitigation Grant Program
GHMO	Guam Hazard Mitigation Officer (State Hazard Mitigation Officer)
GHS/OCD	Guam Homeland Security/Office of Civil Defense
GHURA	Guam Housing and Urban Renewal Authority
GIAA	Guam International Airport Authority
GIS	Geographic Information System
GMH	Guam Memorial Hospital
GMHA	Guam Memorial Hospital Authority
GPA	Guam Power Authority
GSHAP	Global Seismic Hazard Assessment Program
GWA	Guam Waterworks Authority
HAZMAT	hazardous material
HAZUS	Hazards United States
HAZUS-MH	Hazards United States Multi-Hazard
HMAC	Hazard Mitigation Advisory Committee
HMGP	Hazard Mitigation Grant Program
HMP	Hazard Mitigation Plan
HS	Homeland Security
HSGP	Homeland Security Grant Program
HUD	U.S. Department of Housing and Urban Development
HURISK	Hurricane Risk model
IA	Individual Assistance
IBC	International Building Code
IRC	International Residential Code
M	magnitude

MM	Modified Mercalli (Intensity Scale)
mph	miles per hour
MRSA	Methicillin-resistant Staphylococcus aureus
MSAW	minimum safe altitude warning
NCDC	National Climatic Data Center
NCTS	Naval Information, Computer, and Telecommunications Area Master Station
NFIP	National Flood Insurance Program
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
NTSB	National Transportation Safety Board
NWS-WFO	National Weather Service–Weather Forecast Office
OIE	Office International des Epizooties
PA	Public Assistance (Program)
PAG	Port Authority of Guam
PDM	Pre-Disaster Mitigation
PGA	peak ground acceleration
PMEL	Pacific Marine Environmental Laboratory
PSC	Pacific Services Center
PSGP	Port Security Grant Program
RAC	Response Activity Coordinator
RCO	Recovery Coordination Office
RFC	Repetitive Flood Claim (Program)
RL	Repetitive Loss
SAFER	Staffing for Adequate Fire and Emergency Response
SBA	Small Business Administration
SEDS	Social and Economic Development Strategies
SFHA	Special Flood Hazard Area
SPR	Stakeholder Preparedness Review
SRL	Severe Repetitive Loss (Program)
Stafford Act	Robert T. Stafford Disaster Relief and Emergency Assistance Act of 1988
THIRA	Threat and Hazard Identification, and Risk Assessment

USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
U.S.	United States
USGS	U.S. Geological Survey
VS	Veterinary Services
WERI	Water and Environmental Research Institute of the Western Pacific, University of Guam

GOVERNMENT OF GUAM

Governor of Guam

Honorable Lourdes A. Leon Guerrero

Lieutenant Governor of Guam

Honorable Joshua F. Tenorio

Hazard Mitigation Advisory Committee

Anthony Babauta – Office of the Governor

P. Tim Aguon - Guam Homeland Security / Office of Civil Defense
Charles Esteves - Guam Homeland Security / Office of Civil Defense

David Peredo - American Red Cross; Guam Voluntary Organization Active in Disasters
Edwin Reyes - Bureau of Statistics and Plans
Jesse Rojas - Bureau of Statistics and Plans
Jack Hattig – Chamoru Land Trust Commission
John Pangelinan – Customs and Quarantine Agency
Elaine Ayuyu - Department of Administration
Rolando Delfin - Department of Agriculture; Mariana Regional Fusion Center
Peter Terlaje - Department of Agriculture
Bruce Flores - Department of Correction
Jeffrey Warfield – Department of Integrated Services for Individuals with Disabilities
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Joseph Borja - Department of Land Management
Penmar Gulac - Department of Land Management
Rudy Manglona - Department of Parks and Recreation
Annette Aguon - Department of Public Health and Social Services
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Engracia Valencia - Department of Public Health and Social Services

Jesse Garcia - Department of Public Works

Todd Gillan - Department of Public Works

Joseph Guevara - Department of Public Works

Jerome Aguon - Department of Revenue and Taxation

Gregorio Artero - Department of Youth Affairs

Thomas Camacho - Duenas, Camacho & Associates; Guam Society of Professional Engineers; Guam Seismic Advisory Council; Guam Building Code Council

Joseph Angoco - Guam Ancestral Lands Commission

Richard Richards – Guam Behavioral Health and Wellness Center

John Diaz – Guam Community College

Mary Okada – Guam Community College

Christopher Anderson - Guam Department of Education

Taling Taitano – Guam Department of Education

Patrick Guzman – Guam Economic Development Authority

Austin Grant – Guam Economic Development Authority

Ed Aranza - Guam Environmental Protection Agency

Roland Gutierrez - Guam Environmental Protection Agency

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Jaimie Cruz - Guam Homeland Security / Office of Civil Defense

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Michelle Galang - Guam Homeland Security / Office of Civil Defense

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Maria-Loralyn Romulo - Guam Homeland Security / Office of Civil Defense

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Angela Camacho - Guam Housing Corporation

Alice Taijeron - Guam Housing Corporation

Peter Camacho - Guam International Airport Authority

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Michael Poblete - Guam Memorial Hospital Authority

Farinmalin Mondia – Guam National Guard

Joseph Santiago - Guam National Guard

Fred Chargualaf - Guam Police Department; Mariana Regional Fusion Center

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Joseph Tadeo - Guam Waterworks Authority

Francisco Paulino – Joint Region Marianas; Naval Facilities Guam

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Donna Lizama-Acosta - Port Authority of Guam

Joe Javellana - Port Authority of Guam

Brent Wiese – RIM Architects; Guam Building Code Council

Michael Makio - Taniguchi, Ruth, Makio & Associates; American Institute of Architects Guam & Micronesia; Guam Seismic Advisory Council

Romina King - University of Guam / NASA-EPSCoR; Pacific Islands Climate Adaptation Science Center

Sharam Khosrowpanah - University of Guam / School of Engineering

Mark Lander - University of Guam / Water and Environmental Research Institute

Marco Fernandez – 35th Guam Legislature

1.1 PURPOSE

The purpose of this section is to describe and meet the prerequisite requirements for consideration of the 2019 Guam Hazard Mitigation Plan (HMP) by the Federal Emergency Management Agency (FEMA). This effort consists of (1) a review of the Disaster Mitigation Act of 2000 (DMA 2000) requirements and adoption of the plan and (2) additional assurances.

1.2 OFFICIAL RECORD OF ADOPTION

The 2019 Guam HMP meets the requirements of Section 409 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act of 1988 (Stafford Act) and Section 322 of DMA 2000, including the requirement that the plan be adopted by the Government of Guam.

The 2019 Guam HMP has been prepared by Guam Homeland Security/Office of Civil Defense (GHS/OCD) and adopted by the Governor and the Lieutenant Governor of Guam through the issuance of Executive Order 2019-____ dated July __, 2019, which is included in **Appendix A** (Adoption Resolution).

1.3 ADDITIONAL ASSURANCES

The Government of Guam will also comply with all applicable federal statutes and regulations in effect with respect to the periods for which it receives grant funding, as required in 44 Code of Federal Regulations (C.F.R.) 13.11(c). Furthermore, the 2019 Guam HMP will be updated whenever necessary to reflect changes in Guam or federal laws and statutes, as required in 44 C.F.R. 13.11(d). These assurances are included in Executive Order 2019-__, which is included in **Appendix A** (Adoption Resolution).

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2.1 PURPOSE

The purpose of this section is to provide an overview of the 2019 Guam HMP, a discussion of the authority under which the plan was prepared and adopted, and a disclaimer regarding the HMP and HMP update process.

2.2 OVERVIEW

As a condition of receiving federal disaster mitigation funds, the 2019 Guam HMP must meet the requirements of Section 409 of the Stafford Act and Section 322 of DMA 2000. Section 322 of DMA 2000 requires that all U.S. states and territories have a mitigation plan in place that describes the planning process for identifying hazards, risk, and vulnerabilities, identifies and prioritizes mitigation actions, encourages the development of local mitigation, and provides technical support for these efforts.

DMA 2000 addresses a range of topics focused primarily on the importance of pre-disaster infrastructure mitigation planning to reduce disaster losses nationwide and the control and streamlining of the administration of federal disaster relief and programs to promote mitigation activities. According to the Stafford Act, the purpose of Title I, Predisaster Hazard Mitigation, is:

> *…to establish a national disaster hazard mitigation program –*
>
> *(1) to reduce the loss of life and property, human suffering, economic disruption, and disaster assistance costs resulting from natural disasters; and*
>
> *(2) to provide a source of predisaster hazard mitigation funding that will assist States and local governments (including Indian tribes) in implementing effective hazard mitigation measures that are designed to ensure the continued functionality of critical services and facilities after a natural disaster.*

Major provisions of the Stafford Act include funding for pre-disaster mitigation activities, developing multi-hazard maps to better understand risk, establishing state and local government infrastructure mitigation planning requirements, defining how states can assume more responsibility in managing the Hazard Mitigation Grant Program (HMGP), and adjusting ways in which management costs for projects are funded.

On February 26, 2002, FEMA published an Interim Final Rule in the Federal Register that established the hazard mitigation planning requirements enacted in DMA 2000. This rule addresses state mitigation planning, identifies new local mitigation planning requirements, authorizes HMGP funds and Pre-Disaster Mitigation (PDM) funds for planning activities, and increases the amount of HMGP funds available to states that develop a comprehensive mitigation plan. This rule also requires that repairs or construction funded by a disaster loan or grant must be carried out in accordance with applicable standards and states that FEMA may require safe land use and construction practices as a condition of grantees receiving disaster assistance under the Stafford Act. FEMA published a new Interim Final Rule in the October 1, 2002, Federal Register. The primary purpose of this rule was to extend the date by which state and local mitigation plans must be completed to be eligible for post-disaster assistance from November 1, 2003, to November 1, 2004.

FEMA prepared further guidance to assist state, local, and tribal governments to meet the new DMA 2000 planning requirements through a document titled *State and Local Plan Interim Criteria Under the Disaster Mitigation Act of 2000.* The document has two major objectives:

- To help federal and state reviewers evaluate mitigation plans from different jurisdictions in a fair and consistent manner
- To help state and local jurisdictions develop new mitigation plans or modify existing ones in accordance with the Section 322 criteria

The state mitigation planning requirements are identified in their appropriate sections throughout this 2019 Guam HMP and in **Appendix B** (FEMA Crosswalk).

2.3 AUTHORITY

The plan is a living document that will be updated every 5 years, as required by DMA 2000. During the 5 years before an update, the plan should be implemented as much as possible to create an increasingly strong "all hazards" mitigation environment and a sustainable "all hazards" mitigation community on Guam.

The GHS/OCD has prepared the plan. The Guam Hazard Mitigation Officer (GHMO) led the effort, with significant assistance from numerous Government of Guam agencies, other interested parties within the Hazard Mitigation Advisory Committee (HMAC). FEMA Region IX provided technical assistance to GHS/OCD and HMAC during the update process. A complete list of the parties involved is provided in the Acknowledgements and **Section 3** (Planning Process Documentation).

The 2019 Guam HMP is authorized by the Guam Civil Defense Act of 1951, as amended by Public Law 24-298 (included in Original Government Code of Guam enacted by Public Law 1-88, 1952), and Executive Order 97-18 relative to establishing a Civil Defense Advisory Council and the HMAC. Public Law 20-147, Chapter II of Title LXV (Comprehensive Planning), also serves to support the Government of Guam's hazard mitigation activities.

The 2019 Guam HMP is adopted by the Governor of Guam by the issuance of an Executive Order.

2.4 DISCLAIMER

It is important to note that the 2019 Guam HMP was prepared using the best available data at the time of preparation. Significant time and resources were expended to involve all relevant parties, gather all available information, review and rectify data, conduct and interpret analyses, discuss findings, and reach consensus regarding the findings. However, numerous and sometimes significant hurdles were encountered during plan preparation. Some of these issues were resolved, but some will have to be addressed before or during the next plan update in 5 years.

The analyses and associated maps in the 2019 Guam HMP indicate potential exposure (susceptibility) to the hazards, but do not indicate the probability or magnitude of specific hazard events. The maps and analyses in this report are not intended to be relied on as the sole source of information regarding potential exposure (susceptibility) to hazard events, and these maps and analyses should not be used to predict the probability or magnitude of specific hazard events or the potential damage from a hazard event at a specific location.

The 2019 Guam HMP is designed as an instrument of mitigation, primarily for natural disasters and other environmentally related events. Although some human involvement is implied with many of the hazards profiled herein, this document is not intended to address the prevention or mitigation of the possible impacts from terrorist activity. The term *terrorism* encompasses intentional, criminal, or malicious acts involving weapons of mass destruction, including biological, chemical, nuclear, and radiological weapons; arson, incendiary, explosive, and armed attacks; industrial sabotage and intentional hazardous material (HAZMAT) releases; and cyber terrorism (attacks by means of computer). Therefore, it is not the intent of the 2019 Guam HMP to preemptively address these specific events.

Definitions of the key terms found throughout this document are provided in **Appendix C** (Definitions).

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3.1 PURPOSE

The purpose of this section is to describe the process undertaken to prepare the 2019 Guam HMP. Specifically, this section discusses documentation of the planning process (including the DMA 2000 regulatory requirements), coordination among agencies, and program integration.

3.2 DOCUMENTATION OF PLANNING PROCESS

The DMA 2000 requirements for consideration by FEMA for documentation of the planning process are shown below and addressed in the following text.

DMA 2000 REQUIREMENTS - PLANNING PROCESS - DOCUMENTATION OF THE PLANNING PROCESS
Documentation of the Planning Process Requirement § 201.4(c)(1): *[The State plan **must** include a] description of the planning process used to develop the plan, including how it was prepared, who was involved in the process, and how other agencies participated.*
Element A. Does the plan describe the current update process, including: how the plan was prepared, schedule or timeframe, specific milestones and activities, and agencies and stakeholders who were involved. B. Does the plan describe how other state and Federal agencies and other stakeholders were involved in the process? C. Does the plan describe how the state coordinated with other agencies and stakeholders responsible for emergency management, economic development, land use/development, housing, health/social services, infrastructure, and/or natural/cultural resources? D. Does the plan describe limitations in sectors where coordination with agencies and stakeholders is not practicable? *Source: FEMA 2008.*

3.2.1 HMP Development Process, 2003–2005

The initial basis for this plan was the 2003 Guam HMP, which was intended to comply with Sections 404, 406, and 409 of the Stafford Act. The primary purpose of this plan was to meet the requirements necessary to access funding under the HMGP and Public Assistance (PA) program.

The GHS/OCD prepared the plan. The GHS/OCD was supported in preparing the plan by the HMAC, led by the GHMO, and with assistance from numerous Government of Guam agencies and other interested parties. In addition to the GHS/OCD, HMAC membership included representatives from the following agencies: Bureau of Statistics and Plans (BSP), Chamorro Land Trust Commission, Guam Environmental Protection Agency (GEPA), Department of Land Management (DLM), Department of Public Works (DPW), Guam Society of Professional Engineers, Guam Chapter of American Institute of Architects, Guam Consolidated Commission on Utilities, and the Mayors' Council of Guam.

The first update of the 2003 Guam HMP occurred primarily during the 8-month period from June 2004 to February 2005. During this period, the GHMO, its consultant, the HMAC, and other interested parties worked closely together to update the plan.

To initiate efforts to bring the plan into compliance with DMA 2000, the first plan preparation meeting of the HMAC and other interested parties was held on July 7, 2004. The meeting was attended by over 25 individuals, including representatives from approximately 20 Government of

Guam agencies. The GHMO led the meeting, with support by the consultant; topics addressed included explaining hazard mitigation planning and DMA 2000, creating the plan, and identifying potential hazards and assets at risk.

In the week after the first meeting, the GHMO and consultant conducted over 25 individual meetings with nearly all Government of Guam agencies and other relevant on-island parties. The purpose of these meetings was to gather information that could contribute to the preparation of the plan, including risk assessment data/maps, and suggested mitigation strategy actions.

During the approximately 8 weeks before the next HMAC meeting, the GHMO and consultant focused on completing the draft risk assessment, the draft capability assessment, and the draft mitigation strategy. This work required a high level of interaction between the GHMO, HMAC members, the planning consultant, and other relevant parties.

A second meeting of the HMAC and other interested parties was held on September 7, 2004. The meeting was attended by 15 individuals, including a quorum of the HMAC and representatives from 13 Government of Guam agencies. The GHMO led the meeting, with support by the consultant; topics addressed included reviewing the draft risk assessment and creating potential mitigation goals, objectives, and actions.

After the second meeting, members of the HMAC were asked to take a day and a half to consider an implementation strategy for the top 50 hazard mitigation actions (28 of which were existing HMGP project applications and 22 of which were new). The third meeting of the HMAC was held on September 9, 2004. The purpose of the meeting was to discuss the implementation strategy. The meeting was attended by 22 individuals, including a quorum of the HMAC and representatives from 13 Government of Guam agencies. The GHMO led the meeting, with support by the consultant; topics addressed included completing the implementation strategy and outlining the plan maintenance procedures.

Approximately 1 month after the third 2005 Guam HMP preparation meeting, the GHMO, with support from the consultant, prepared a Draft 2005 Guam HMP and submitted the draft document to FEMA for a courtesy review on October 10, 2004. Concurrently, the GHMO presented the Draft Guam 2005 HMP to HMAC members for review and comment. In early November, the GHMO, with support from the consultant, reviewed and incorporated comments received by FEMA and HMAC members. The GHMO then submitted a Final Draft 2005 Guam HMP to the Governor and Lieutenant Governor’s offices for review. In February 2005, the GHMO incorporated all revisions made by the Governor and Lieutenant Governor’s offices and resubmitted the Final 2005 Guam HMP to both offices for adoption by Executive Order. The Governor and Lieutenant Governor signed Executive Order 2005-06, adopting the Final 2005 Guam HMP on February 24, 2005.

3.2.2 HMP Update Process, 2008

As noted in **Section 2** (Background), the 2005 Guam HMP was a living document that would be updated every 3 years, as required by DMA 2000. As such, the first plan update was prepared during a 3-month period from February through April 2008.

To kick off the 2008 Guam HMP update process, during the first week of January 2008, the HMAC reviewed and analyzed each section of the 2005 Guam HMP to determine the areas that warranted an update and those that did not.

After the GHMO, HMAC, and the consultant determined the course of action and implementation schedule to complete the plan update, the GHMO organized the first HMAC meeting of 2008. The first HMAC meeting was held on February 13 and was attended by 17 individuals, including representatives from Government of Guam agencies and other organizations. The topics that HMO and the consultant addressed included HMAC introductions, overview of the DMA 2000 and previous planning efforts, the hazards profiled and assets inventoried in the 2005 Guam HMP, the plan update schedule, and next steps. During this meeting, the HMAC, after considering recent disaster data, determined that no new hazards would be profiled for this plan update.

In the week after the first meeting, the GHMO and the consultant conducted over a half-dozen individual meetings with Government of Guam agencies, including the GHS/OCD, Governor's Office, BSP, GWA, DPW, GEPA, DLM, and other relevant on-island parties, including the National Weather Service–Weather Forecast Office Guam (NWS–WFO Guam). The purpose of these meetings was to update existing information and gather new information that could contribute to preparation of the plan, including asset and hazard data, Geographic Information System (GIS) information, hazard mitigation–related plans and policies, and mitigation actions.

During the approximately 2 weeks between the first and second HMAC meetings, the GHMO and the consultant focused on completing the draft risk assessment, the capability assessment, and the mitigation actions. This work required a high level of interaction between the GHMO, HMAC members, the consultant, and other relevant parties.

A second meeting of the HMAC and other interested parties was held on March 4, 2008. The meeting was attended by eight individuals, representing six HMAC agencies. The meeting, which was led by the GHMO and supported by the consultant, focused on the draft risk assessment. As such, the HMAC reviewed updated assets (e.g., 2008 building footprints) and figures (e.g., the 2007 Flood Insurance Rate Map [FIRM]) and examined corresponding draft vulnerability analysis tables. Next, the HMAC reviewed and revised the draft list of goals, objectives, and actions to be included in the mitigation strategy.

After the second meeting, members of the HMAC were asked to take a day to consider the mitigation actions to include in the implementation strategy. The GHMO asked each HMAC member to select mitigation actions using a scoring system based on the evaluation criteria handed out at the second HMAC meeting. The third meeting of the HMAC was held on March 6, 2008, to discuss the implementation strategy. This meeting was attended by seven HMAC members and representatives and the Guam Historic Preservation Officer. The GHMO led the meeting, with support by the consultant; topics addressed included reviewing the mitigation actions selected by the HMAC scoring process and the GHMO. During this meeting, the HMAC members also reviewed and revised the implementation strategy and the consultant outlined the plan maintenance procedures.

Approximately 2 weeks after the third plan preparation meeting, the GHMO, with support from the consultant, prepared a Draft 2008 Guam HMP, and submitted the draft document to FEMA for a courtesy review on March 21, 2008. Concurrently, the GHMO presented the Draft 2008 Guam HMP to HMAC members for review and comment. In early April, the GHMO, with support from the consultant, reviewed and incorporated comments received from FEMA and HMAC members. The GHMO then submitted an Administrative Final HMP to the Governor and Lieutenant Governor's offices for review. On April 11, 2008, HMO, with support from the consultant, incorporated all revisions made by the Governor and Lieutenant Governor's offices and resubmitted the Final HMP to both offices for adoption by Executive Order. The Governor and Lieutenant Governor signed Executive Order 2008-05, adopting the Final 2008 Guam HMP on April 22, 2008.

3.2.3 HMP Update Process, 2011

The 2011 Guam HMP update was prepared during a 3-month period from February through April 2011. To kick off the update process, during the second week of February 2011, the GHMO, GHS/OCD Mitigation staff, and the consultant reviewed and analyzed each section of the 2008 Guam HMP to determine which areas warranted an update and which ones did not.

After the GHMO, GHS/OCD Mitigation staff, and the consultant determined the draft course of action and implementation schedule to complete the plan update, the GHMO organized the first HMAC meeting of 2011. The first HMAC meeting was held on February 24, 2011, and was attended by 32 individuals, including representatives from Government of Guam agencies and other organizations. Topics addressed by the GHMO and the consultant included HMAC introductions, overview of the DMA 2000 and previous planning efforts, the hazards profiled and assets inventoried in the 2008 Guam HMP, the plan update schedule, and next steps. During this meeting, the HMAC determined that the tropical cyclone subhazards should be broken out as separate stand-alone hazards. The HMAC also decided that three additional hazards should be profiled in the updated plan: non-seismic ground failure hazards (sinkholes), slope failure (landslide, mudslide, and post-fire debris flow), and terrorism. The consultant asked the HMAC to review the 2008 Guam HMP and provide any additional recommendations not identified in the draft course of action prior to the second HMAC meeting.

In the week after the first meeting, the GHMO and the consultant met with the BSP to obtain updated asset information, the NWS-WFO Guam to obtain input on hazard profile information, and the Water and Environmental Research Institute of the Western Pacific, University of Guam (WERI), to obtain climate change information.

During the approximately two weeks between the first and the second HMAC meetings, the HMO and the consultant focused on completing the draft risk assessment and updating the planning process, island description, and plan maintenance sections.

A second meeting of the HMAC and other interested parties was held on March 17, 2011. The meeting was attended by 18 individuals. The meeting, which was led by the GHMO and supported by the consultant, focused on reviewing the draft risk assessment, revising the list of potential mitigation actions, and selecting high-priority mitigation actions to be included in the implementation strategy.

Approximately 1 week after the second HMAC meeting, the GHMO, with support from the consultant, prepared a Draft 2011 Guam HMP. The GHMO presented the draft document to the HMAC for review and comment. At the beginning of April 2011, the GHMO, with support from the consultant, reviewed and incorporated comments received by the HMAC. The GHMO then submitted the Final Draft 2011 Guam HMP to FEMA and the Governor and Lieutenant Governor's offices for review. The Governor and Lieutenant Governor signed Executive Order adopting the Final 2011 Guam HMP on April 20, 2011.

3.2.4 HMP Update Process, 2014

The 2014 Guam HMP update was prepared during a 2-month period from mid-February through mid-April 2014. To kick off the update process, during the last week of February, the GHMO, GHS/OCD Mitigation staff, and consultant reviewed and analyzed each section of the 2011 Guam HMP to determine which areas warranted an update and which ones did not.

After the GHMO, GHS/OCD Mitigation staff, and consultant determined the draft course of action and implementation schedule to complete the plan update, the GHMO organized the first HMAC meeting of the 2014 Guam HMP update process. The first HMAC meeting was held on March over three days (March 13, March 14, and March 17) and included representatives from the 24 Government of Guam agencies and other organizations. Topics addressed by the GHMO included HMAC introductions, an overview of the DMA 2000 and previous planning efforts and current plan update efforts, and a group review of the hazards profiled and assets inventoried in the 2011 Guam HMP. During this meeting, the GHMO announced that sea level rise would be addressed as a new hazard in the Guam HMP.

Also during the month of March, the GHS/OCD Mitigation staff obtained updated hazard information from various Government of Guam agencies as well as the NWS–WFO Guam and Water and Environmental Research Institute of the Western Pacific (WERI), University of Guam. Using this updated information the GHMO, GHS/OCD Mitigation staff and the consultant worked together to update the hazard profiles. In addition, the GHS/OCD Mitigation staff updated the island description and plan maintenance sections.

A second meeting of the HMAC was held on March 21, 2014. The meeting, which was led by the GHMO, focused on the review of the 2011 Guam HMP's implementation strategy to determine which mitigation actions had been implemented and which had not. On March 28, the HMAC met again to develop a list of new mitigation actions to be considered for the 2014 Guam HMP's implementing strategy. On March 28, 2014 the HMAC members met for a third time to finalize list of mitigation actions to be included in 2014 Guam HMP's implementation strategy. Members of the HMAC also met on April 1, 2014 to discuss GIS information collection and analysis.

On April 8, 2014 the GHMO sent out the Draft 2014 Guam HMP to the HMAC to review. On April 10, 2014 the HMAC came together for a final meeting to discuss the draft and to endorse to the Governor for adoption by Executive Order. The GHMO then submitted the Final Draft 2014 Guam HMP to FEMA and the Governor's office. The Governor signed Executive Order No. 2014-11, adopting the Final 2014 Guam HMP on April 25, 2014.

3.2.5 HMP Update Process, 2019

The 2019 Guam HMP update which was planned to be done in-house has been in the agenda of the past 3 Quarterly Response Activity Coordinators (RAC)/Emergency Support Function (ESF) Coordinators Workshops. Updated data and copies of new studies, and hazards and risk assessments have been requested

On March 25-26, 2019, GHS/OCD conducted the Hazard Mitigation Strategies and Opportunities Workshop at The Westin Resort Guam in Tumon, Guam. This first ever mitigation workshop, which will now be an annual event, was supported by FEMA, the Western States Policy Council (WSSPC), HMAC, Guam Seismic Advisory Council (GSAC), Guam Building

Code Council, Tsunami/Storm Ready Committee, Guam Society of Professional Engineers, American Institute of Architects – Guam and Micronesia Chapter, Joint Region Marianas, Government of Guam agencies, and private sector partner organizations. The workshop provided a forum discussing Guam's mitigation strategies and opportunities including the jurisdiction's hazards and risks. The goals of the workshop were as follows:

a. Assemble a wide range of stakeholders and mitigation professionals, familiarize with everyone's work and mandates, and collectively build on our resources and opportunities for improvement.
b. Provide a clear understanding of the earthquake, tsunami and other hazards vulnerability assessments/risk analysis, mitigation strategies, various policies, plans, and relevant systems and how they are integrated.
c. Provide clear understanding of federal, territorial, private industry, non-governmental and partner organizations mitigation efforts, current and planned.
d. Provide capability status of supporting resources during responses to catastrophic scenarios.
e. Support the ongoing effort of updating the 2014 Guam HMP.

The 2019 Guam HMP update was prepared during 4-month period from March through June 2019. On March 27-29, 2019, FEMA Region IX Mitigation Division provided technical assistance to GHS/OCD Mitigation staff on the critical task to update the 2014 Guam HMP. To kick off the update process, the GHMO, GHS/OCD Mitigation staff, and a FEMA Region IX Mitigation Division representative with the support of other FEMA Mitigation Division staff off-site reviewed and analyzed the 2014 Guam HMP to determine which areas warranted an update.

A Mitigation Projects and Strategy Meeting, of the HMAC was held on May 10, 2019 in the GHS/OCD Emergency Operations Center. The meeting, which was led by the GHMO, focused on the review of the 2019 Guam HMP's implementation strategy to determine which mitigation actions had been implemented and which had not. The meeting was also to get the HMAC to submit potential mitigation projects. HMAC met again to develop a list of new mitigation actions to be considered for the 2019 Guam HMP's implementing strategy. After which, the HMAC members and sub-working groups met on separate occasions to finalize the list of mitigation actions to be included in 2019 Guam HMP's implementation strategy. With support of the Guam GIS Users Group, members of the HMAC also discussed GIS data layers, information collection and analysis.

Also during the month of May and June, the GHS/OCD Mitigation staff obtained updated hazard information, new hazard studies, and mitigation actions from various Government of Guam agencies as well as the NWS–WFO Guam, Water and Environmental Research Institute of the Western Pacific (WERI) of the University of Guam, and other organizations. Using this updated information the Guam HMO updated the Risk Assessment and Mitigation Strategy sections. In addition, the GHS/OCD Mitigation staff updated all other sections.

Following the Region IX Mitigation Clubhouse Meeting in Oakland, California, on June 24-26, 2019, FEMA Region IX Mitigation Division provided technical assistance to GHS/OCD Mitigation staff relative to 2019 Guam HMP.

Starting April 23, 2019, the GHMO sent out the Draft 2019 Guam HMP to HMAC to review. Separate meetings by workgroups, task forces, emergency support functions and disciplines followed. The 2019 Guam HMP update process was fully supported by the whole community. The collaborative data collection and mitigation strategy development were participated by various government agencies and private sector partners responsible for the following: emergency management and homeland security; economic development; land use planning and development; housing; public health and social services; infrastructure services; and natural and cultural resources. The government agencies and private sector partner organizations are listed in the expanded membership of the HMAC in Table 3-1.

It was noted, however, that the turnover of personnel and the absence of central repository of data and planning documents hindered the momentum and impacted the efficiency of the HMAC and support agencies during the plan update process.

On July 9, 2019, the HMAC and agency Response Activity Coordinators (RAC)/Emergency Support Function (ESF) Coordinators came together for a final workshop to discuss the draft plan. The GHMO then submitted the Final Draft 2019 Guam HMP to FEMA and the Governor of Guam via the Governor's Authorized Representative (GAR). The Governor signed Executive Order No. 2019-___, adopting the 2019 Guam HMP on July XX, 2019.

3.2.6 Hazard Mitigation Advisory Committee

Table 3-1 identifies the 38 Government of Guam departments/agencies, advisory councils and commissions; private sector partners, and Federal agencies that made up the HMAC for the 2019 Guam HMP update process. A description of the Guam HMP update activities by the HMAC is described in **Section 3.2.5** (HMP Update Process, 2019). The department and agency representatives that attended HMAC meetings, provided additional information to the Guam HMP update process. They are also listed in the **Acknowledgements** at the beginning of this Guam HMP.

Table 3-1 Hazard Mitigation Advisory Committee

Committee Participants	
Office of the Governor	Guam Homeland Security/Office of Civil Defense
American Red Cross	Guam Hotel and Restaurant Association
Bureau of Statistics and Plans	Guam Housing and Urban Renewal Authority
Chamoru Land Trust Commission	Guam Housing Corporation
Customs & Quarantine Agency	Guam International Airport Authority
Department of Administration	Guam Memorial Hospital Authority
Department of Agriculture	Guam National Guard
Department of Correction	Guam Police Department
Department of Integrated Services for Individuals with Disabilities	Guam Power Authority
Department of Land Management	Guam Visitors Bureau
Department of Parks and Recreation	Guam Voluntary Organizations Active in Disaster (Includes Catholic Social Services, The Salvation Army, Governor's Serve Guam Commission, and other faith-based organizations)
Department of Public Health and Social Services	Guam Waterworks Authority

Department of Public Works	Joint Region Marianas (Includes Naval Facilities Guam)
Department of Revenue and Taxation	Mariana Regional Fusion Center
Department of Youth Affairs	Mayors' Council of Guam
Duenas, Camacho & Associates, Inc. (Also representing the Guam Seismic Advisory Council and the Guam Building Code Council)	National Weather Service – Weather Forecast Office Guam (Also representing the Guam TsunamiReady/ StormReady Committee)
Guam Ancestral Lands Commission	Office of Technology
Guam Behavioral Health & Wellness Center	Port Authority of Guam
Guam Community College	RIM Architects
Guam Department of Education	Taniguchi-Ruth-Makio Architects (Also representing the American Institute of Architects, Guam and Micronesia Chapter)
Guam Economic Development Authority	University of Guam (Also representing the Water and Environmental Research Institute)
Guam Environmental Protection Agency	35th Guam Legislature
Guam Fire Department	

3.2.7 Review of the 2014 Guam HMP and Proposed Revisions

As noted in **Section 3.2.4** (HMP Update Process, 2019), to kick off the 2019 Guam HMP update process, the GHMO and GHS/OCD Mitigation staff reviewed and analyzed the 2014 Guam HMP to determine which areas warranted an update. The HMAC was also asked to review the 2014 Guam HMP and provide additional input. A summary of the review and revisions that were made to the 2014 Guam HMP to create the 2019 Guam HMP is provided below in **Table 3-2**.

Table 3-2 2014 Guam HMP Review and Revisions

2014 Guam HMP	Actions Needed to Be Taken for 2019 Guam HMP
Section 1, Prerequisites	Readopt the Guam HMP by the Governor and/or the Lieutenant Governor of Guam by signature of Executive Order
Section 2, Background	No action needed
Section 3, Planning Process Documentation	Update HMAC membership Reconvene the HMAC to assist in the plan update Confirm previous and current program integration efforts Document entire plan update process
Section 4, Island Description	Document any changes to the Government of Guam since 2014 Update population data using the 2010 Census Determine if/how EFMUTS should be updated – consider developing a new table that identifies EFMUTS built between 2011-2018 but doesn't include in the vulnerability analysis Gather and update information on tourism arrivals and building permits issued through 2018 Document development trends, including a general discussion on military buildup
Section 5, Risk Assessment	Include sea level rise (which may include the various impacts of climate change) as a new hazard and profile hazard

Table 3-2 2014 Guam HMP Review and Revisions

2014 Guam HMP	Actions Needed to Be Taken for 2019 Guam HMP
	Update previous occurrences for all hazards profiled Conduct vulnerability analysis using updated asset and hazard information, interpret analysis, and discuss new findings Update population figure and local and regional historical seismicity figures
Section 6, Mitigation Strategy	Include new mitigation plans/policies in the capability assessment table Review and update available federal and local funding sources Review the 2014 implementation strategy and determine status and relevancy for inclusion in the 2019 potential mitigation actions list Document completed 2014 mitigation actions in the plan maintenance section Incorporate new mitigation actions from state plans and policies based on the updated risk assessment developed by the HMAC and other interested organizations Prioritize mitigation actions for the implementation strategy Determine the implementation strategy for selected mitigation actions
Section 7, Plan Maintenance Process	Review the plan maintenance process with the GHMO to determine what worked and what did not work After discussion/analysis with the GHMO, revise the plan maintenance process, as needed
Section 8, References	Include new sources

3.3 COORDINATION AMONG AGENCIES

The DMA 2000 requirements for consideration by FEMA for coordination among agencies, which are recommended but not required, are shown below and addressed as follows.

DMA 2000 REQUIREMENTS - PLANNING PROCESS - COORDINATION AMONG AGENCIES
Coordination among Agencies Requirement § 201.4(b): *The [State] mitigation planning process* ***should*** *include coordination with other State agencies, appropriate Federal agencies, interested groups, and …*
Element A. Does the new or updated plan describe how Federal and State agencies were involved in the planning process? B. Does the new or updated plan describe how interested groups (i.e., businesses, non-profit organizations, and other interested parties) were involved in the planning process? C. Does the updated plan discuss how coordination among Federal and State agencies changed since approval of the previous plan? Source: FEMA 2008.

3.3.1 Federal and State Agency Involvement and Coordination

The involvement of the HMAC in the 2014 Guam HMP update is discussed in **Section 3.2.5** (HMP Update Process, 2019) and **Section 3.2.6** (Hazard Mitigation Advisory Committee). The HMAC includes more agencies and organizations compared to those that participated in the 2014 Guam HMP update. The GHS/OCD coordinated with other organizations, including UOG WERI and the NWS-WFO Guam, for new and updated hazard information. FEMA Region IX Mitigation Division extended technical assistance to GHS/OCD during the planning process.

3.3.2 Stakeholders Engagement

Interested groups and concerned residents were engaged during the 2019 Guam HMP update process. The Response Activity Coordinators (RAC)/Emergency Support Function (ESF) Coordinators were engaged during the past three (3) quarterly workshops, specific workgroup meetings of which followed. On March 25 and 26, GHS/OCD conducted the first annual Hazard Mitigation Strategies and Opportunities Workshop at The Westin Resort Guam in Tumon, Guam. The workshop provided a forum discussing Guam's mitigation strategies and opportunities involving hazards and risks that assembled a wide range of stakeholders and mitigation professionals.

In addition to having the 2019 Guam HMP posted in the GHS/OCD website, during the week of April 22, 2019, the GHMO posted the draft document to the GHS/OCD FTP site; the posting included the contact details for the GHMO to facilitate public comments. The GHMO also met with key stakeholders individually for further clarifications, collaboration, and information gathering. After adoption and approval of the 2019 Guam HMP, the GHS/OCD will issue a press release announcing the completion of the 2019 Guam HMP and its availability for continued public review and comment. Similar to previous planning efforts, the GHMO will distribute copies of the 2019 Guam HMP to the HMAC member agencies/organizations, the Hagatna Public Library, the University of Guam Library, the Guam Community College Library, and the Bureau of Statistics and Plans Library.

3.4 PROGRAM INTEGRATION

The DMA 2000 requirements for consideration by FEMA for program integration, which are recommended but not required, are shown below and addressed in the following text.

DMA 2000 REQUIREMENTS - PLANNING PROCESS – PROGRAM INTEGRATION
Program Integration Requirement § 201.4(b): *[The State mitigation planning process should] be integrated to the extent possible with other ongoing State planning efforts as well as other FEMA mitigation programs and initiatives.*
Element A. Was the mitigation planning process integrated to the extent possible with other state planning efforts? Source: FEMA 2008.

During the preparation of the 2011 and 2014 Guam HMP, the GHMO and HMAC have identified several ways in which the risk assessment and mitigation strategy discussed in the 2014 Guam HMP could be integrated with current and future Government of Guam and FEMA planning efforts. These efforts have been updated for the 2019 Guam HMP and include the following:

- Continued integration of the mitigation planning process of the 2019 Guam HMP relative to identification of hazards/threats and assessment of risk addressed in the Threat and Hazard Identification and Risk Assessment (THIRA), Stakeholder Preparedness Review (SPR), National Incident Management System (NIMS) Implementation Self-Assessment and Community Preparedness Guide (CPG) 101 Assessments. The risk assessment of the Guam HMP identifies threats and hazards addressed in Guam's THIRA
- Continued integration of the 2019 Guam HMP as an Annex of the Guam Comprehensive Emergency Management Plan (GCEMP). The GCEMP is due for the next update in 2020.
- Continued integration of the 2019 Guam HMP with the National Flood Insurance Program (NFIP) provisions by the Department of Public Works (DPW) Floodplain Administration as well as Building Permits Section during the review of building proposals. The risk assessment of the 2019 Guam HMP identifies National Flood Insurance Program's (NFIP) Repetitive Loss (RL) and Severe Repetitive Loss (SRL) properties on Guam and the mitigation strategy of the HMP includes mitigation actions to reduce or eliminate damage to these properties.
- Consideration of 2019 Guam HMP by Government of Guam agencies and programs, such as: Bureau of Statistics and Plans (BSP) – Guam Coastal Management Program, Department of Agriculture (DOAg), Department of Land Management (DLM), Department of Public Health and Social Services (DPHSS), Department of Public Works (DPW), Department of Youth Affairs, Guam Community College (GCC), Guam Department of Education (GDOE), Guam Housing and Urban Renewal Authority (GHURA), Guam Memorial Hospital Authority (GMHA), Guam Power Authority (GPA), Guam Solid Waste Authority (GSWA), Guam Waterworks Authority (GWA), University of Guam (UOG), etc., in relation to capital improvement projects (CIPs), and relevant land and development master plans.
- Consideration of 2019 Guam HMP (particularly, the high-priority mitigation actions identified in the 2019 Guam HMP) by GHMO and HMAC for Hazard Mitigation Grant

Program (HMGP), Pre-Disaster Mitigation (PDM) Grant, and Flood Mitigation Assistance (FMA) mitigation projects.

- Consideration of 2019 Guam HMP with the following Federal planning efforts: NOAA Office of Coastal Management Natural Hazards element as developed and applied to Guam’s coastal zone, USGS Rigorously Valuing the Role of US Coral Reefs in Coastal Hazard Risk Reduction, etc.

4.1 PURPOSE

The purpose of this section is to provide basic background information on the Island of Guam. General information is provided concerning geography, climate, government, population, economy, tourism, assets, and planning and development.

4.2 GEOGRAPHY

Located in the western North Pacific Ocean, Guam is the largest and farthest-south island of the chain of volcanic islands that constitute the Mariana Archipelago. The elongated, peanut-shaped island is oriented northeast-southwest, covers an area of 209 square miles, and has approximately 100 miles of coastline. Major features of the island (e.g., major roads, village boundaries) are shown on **Figure D-1**.[1]

Guam can be divided into two primary ecoregions: the southern mountainous part of the island and the northern relatively flat part of the island, with a marine-terrace plateau. Guam is divided into 19 villages. The southern ecoregion contains 9 of the villages: Agat, Asan/Maina, Inarajan, Merizo, Piti, Santa Rita, Talofofo, Umatac, and Yona. The northern ecoregion contains the other 10 villages: Agana Heights (Passan), Hagatna (Agana), Barrigada, Chalan Pago-Ordot, Dededo, Mangilao, Mongmong-Toto-Maite, Sinajana, Tamuning/Tumon, and Yigo.

The southern ecoregion is mountainous, with 11 peaks rising to 1,000 feet or more that form a discontinuous ridge that extends along the southwestern part of the island. Mount Lam Lam is the tallest point on the island with an elevation of 1,332 feet. The western coast of this ecoregion contains a narrow stretch of lowlands, and the eastern coastline contains limestone cliffs. The volcanic rock of the ecoregion has formed into clay-sand residuum-type soils, which are inherently unstable. The various soils of Guam are presented on **Figure D-2,** and the geology of Guam is shown on **Figure D-3**.

Slopes in the southern ecoregion are often very steep. Nonriverine areas either lack vegetation or are covered with a savanna grass community primarily consisting of swordgrass and mission grass. The volcanic terrain contains numerous streams. The four largest streams are the Ylig, Talofofo-Ugum, Inarajan, and the Pago-Lonfit. Riverine areas contain forests with native tropical plants such as nunu, sea-hibiscus, and aggag. Vegetation is mapped on **Figure D-4**.

The western section of the southern ecoregion has a large natural bay. This area has been developed into Apra Harbor, which is Guam’s only seaward port of entry. Fena Reservoir, which is a major source of potable water for Guam, is also in this region. The U.S. Navy operates a large portion of Apra Harbor and a naval magazine is present roughly in the center of this region.

The northern ecoregion is a relatively flat coralline limestone plateau, with steep coastal cliffs and narrow coastal plains that dominate the northern part of the island. The topography of this plateau gently undulates with elevations that vary between 200 to 600 feet. The limestone geology has high permeability, and no substantial streams or rivers exist, but Guam’s largest aquifer and primary source of fresh water is beneath this region. The limestone of the area also

[1] All figures are provided in Appendix D (Figures).

contains sinkholes, which are natural depressions in the ground caused by weathering processes. However, sinkholes also occur in the southern portion of the island.

Five main vegetation-types are associated with the limestone soils of the area. Breadfruit and banyan forests are generally widespread throughout the area; a *Mammea* forest occurs in the eastern escarpment of the northern limestone plateau; *Cordia* scrub-type forest dominates many steep slopes and cliffs of the area; another forest-type is dominated by tall nunu; and a final forest-type is dominated by aggag. The northern section of this ecoregion is operated as Andersen Air Force Base.

The island of Guam is surrounded by living coral reefs. The waters around Guam are very deep; the Marianas Trench, the deepest part of the world's oceans, is directly east of Guam. Low-lying vegetated beaches are found in both the northern and the southern ecoregions of the island. Small swamps, mangrove, and marsh areas are also found along coastal areas of Guam.

4.3 CLIMATE

Guam has a tropical maritime climate, with year-round warm weather, wet and dry seasons, moderate to high humidity, and wind speed and direction that vary with its two primary seasons—the wet season and the dry season. Seasonal temperatures vary approximately 5 degrees Fahrenheit (°F) from one another. The annual-average-maximum temperature is 86°F, and the annual-average-minimum temperature is 76°F. The range of temperature between day and night is approximately 15 to 20 °F. and is larger than the difference between January and July temperatures. The wet season generally lasts from July through December, and the season is characterized by a high annual average relative humidity of around 86 percent and relatively weak winds ranging in direction from southeasterly to southerly. The dry season generally lasts from January through June, and a low annual average relative humidity of around 71 percent characterizes this season. Dry season winds are known as "trade winds", which usually blow from the northeast or east. The trade winds can, and often do, occur for some period of time every month of the year. Average annual rainfall varies from about 80 inches in the central and coastal lowlands up to 110 inches on the more mountainous areas of southern Guam. A wide variation in rainfall can occur from year to year. In 1997, for example, the island recorded around 165 inches of rain. In contrast, in 1998, the island recorded around 55 inches of rain. The contrast from one year to the next differed by a factor of three or by 300%. This illustrates the large range of natural rainfall variability on the island. The year 1997 was a strong El Niño year (wet), while 1998 was the post-El Niño year (dry). From the 1950s to the mid-1990s, official rainfall was measured at Finegayan in northwest Guam—a wetter island area. From the mid-1990s, to the current time, the official rainfall was/is measured at the International airport—a drier area. This explains most of the difference between early rainfall averages of around 100 inches per year and a more current average around 86 inches per year.

Generally, during the wet season a monsoon weather pattern can surge from the vicinity of the Philippines across the western North Pacific. Such a surge can affect Guam with sustained western and southwestern winds ranging from 10 mph up to 45 miles per hour (mph), and lasting from a few days to a few weeks. Rainy conditions generally accompany the winds. The wet season in Guam is punctuated by tropical cyclones that pass near or over Guam. *Tropical cyclone* is a generic term that includes tropical depressions, tropical storms, typhoons, and super typhoons. Typhoons can produce very destructive winds with sustained winds over 150 mph and gusts over 180 mph. These conditions are accompanied by: powerful storm surges and destructive coastal inundation; torrential rains and flooding, single-day rainfall sometimes exceeding 20 inches; wind shear and mechanical turbulence; rough seas and hazardous surf; tornadoes; sea salt deposition; coastal erosion and pollution; and slope failures, including mudslides. The strength of a tropical cyclone as it passes over Guam largely depends on the relative location of the seasonal monsoon weather pattern. For example, typically from September to November, the axis of the monsoon weather pattern continually migrates southward and eastward, taking a position east or southeast of Guam. Therefore, the tropical cyclones that develop during this time tend to do so southeast of Guam and thus move toward the island. They have more time to develop and intensify than do tropical cyclones that develop closer to Guam when the typical monsoon pattern is focused closer to the island. However, typhoons can affect Guam any month of the year.

The El Niño—Southern Oscillation (ENSO) is a phenomenon that involves the east-west oscillation of warm and cold ocean waters along the equatorial Pacific and the east-west oscillation of wet and dry atmospheric weather patterns along the equatorial Pacific. It involves three major phases, El Niño, the warm phase, La Niña, the cold phase, and ENSO-neutral, the intermediate phase that separates the other two phases. El Niño involves the eastward redistribution of warm equatorial oceanic waters to the Central and Eastern Pacific. It usually has a wet phase that generally results in more rainfall and stronger monsoon-related westerly winds on Guam and a dry phase that usually results in a persistent regional drought. Weak El Niño events tend to occur every 3-5 years; moderate events every 7-12 years; and strong events every 20-30 years. During El Niño events, very intense tropical cyclones can develop southwest of Hawaii and travel all the way to Guam. Super Typhoon Paka that devastated Guam in 1997 is an example of a Super Typhoon that occurred during such conditions. The year after a strong El Niño event can be exceptionally dry. For example, rainfall for Guam was around 40 percent of normal from January to June 1998, 6 months after the 1997 El Niño

Another aperiodic climatic event that involves colder-than-normal ocean temperatures in the equatorial central Pacific Ocean is known as La Niña. When this event occurs, it can result in drier-than-normal conditions on Guam during the typical wet season and wetter-than-normal conditions during the typical dry season. During La Niña, the monsoon trough become reverse-oriented, stretching northeast to southwest. As a result, storms tend to develop to the north and west of Guam, making tropical cyclone activity very low for Guam. Other more subtle climate patterns can affect the weather on Guam, usually resulting in upper level systems that cause increased thunderstorm activity over the island.

ENSO-neutral refers to the intermediate phase between an El Niño phase and a La Niña phase. With ENSO-neutral, tropical cyclone activity is less than during an El Niño event but greater than during a La Niña event. Rainfall is closer to average in the wet season and the dry season. Sea level stabilizes toward normal elevations from lower values in El Niño events and from higher values in La Niña events.

Climate change on Guam will likely have its most-immediate impact as an increase in sea level or what is commonly referred to as sea level rise. Most predictions look at a 1-foot rise by 2050 and a 3-foot rise by 2100. Predictions for tropical cyclone activity are not so clear-cut in terms of stronger or weaker storms, larger or smaller storms, or more or fewer storms. However, if nothing changes, the sea level rise itself will increase the coastal inundation effects of the storms. Temperatures will rise and extreme temperature events, which are rare now, will likely become more frequent. Based on computer model runs, changes in rainfall will depend the amount of temperature rise. The most probable changes for Guam will likely be small, at least for the next 50 years. Models suggest a slightly wetter dry season and little change in the wet season. At this time, except for sea level rise, confidence in most other impacts due to changes in climate is low.

4.4 GOVERNMENT

Guam is an unincorporated territory of the United States; policy relations between Guam and the United States are under the jurisdiction of the Office of Insular Affairs, United States Department of the Interior. Guam was acquired by the United States from Spain in 1898 after the Spanish-American War under the Treaty of Paris. Under the Organic Act of 1950, citizens of Guam are required to follow the laws and the Constitution of the United States. Guam citizens are citizens of the United States, but they do not have the right to vote for the President of the United States. Guam elects one nonvoting delegate to the United States House of Representatives. Guam has an elected Governor, a Lieutenant Governor, and a 15-seat unicameral Legislature. Guam has a cabinet of executive departments, whose heads are appointed by the Governor with the consent of the Legislature. Guam has a Federal District Court, with a judge appointed by the President, a Territorial Superior Court, with judges appointed for 8-year terms by the Governor with the consent of the Legislature, and a Territorial Supreme Court, with justices appointed by the Governor with the consent of the Legislature.

As noted earlier, Guam is divided into 19 villages, Agana Heights (Passan), Agat, Asan/Maina, Barrigada, Chalan Pago-Ordot, Dededo, Hagatna (Agana), Inarajan, Mangilao, Merizo, Mongmong-Toto-Maite, Piti, Santa Rita, Sinajana, Talofofo, Tamuning/Tumon, Umatac, Yigo, and Yona. Hagatna (formerly Agana) contains the capital of the island. Each village has an elected mayor and all village Mayors sit on the Mayors' Council of Guam.

Currently, the Government of Guam operates most services and utilities on Guam. These utilities and services include the Guam Fire Department (GFD), Guam Memorial Hospital Authority (GMHA), Guam Police Department (GPD), Guam Power Authority (GPA), and Guam Waterworks Authority (GWA). The Guam Telephone Authority (GTA), the principal provider of telecommunications services on the island, was acquired and privatized in January 2005 by TeleGuam Holdings, LLC, doing business as GTA TeleGuam.

A number of U.S. military bases or installations are found on Guam, including the Andersen Air Force Base in Yigo, and numerous U.S. Navy facilities, including: Apra Harbor Naval Complex; Naval Activities in Santa Rita; Naval Information, Computer, and Tele-Communications Area Master Station (NCTS) Finegayan in Dededo; NCTS in Barrigada; Tiyan; Orote Point; Nimitz Hill in Asan/Maina; and the Ordnance Annex. The Army National Guard also has military installations in Barrigada. The Government of Guam has no authority in these areas, which occupy approximately 29 percent of the island's total land area.

The U.S. Department of Defense has developed the Guam Military Buildup Program, which will involve the movement of forces and equipment of the U.S. Army, Air Force, Marines, and Navy from other areas to Guam. The program was initiated in May 2006 and construction, which will take place at military sites throughout the island, was initially expected to be completed in 2014. However, construction has been delayed and may not be complete until 2020. Once completed, the program will increase the total number of military personnel on active duty from 6,420 to approximately 18,930 (see **Section 4.9.2** [Military Buildup] for additional information).

4.5 POPULATION

The 2010 population in Guam was 159,358. According to U.S. Census, between 2000 and 2010, Guam underwent a 2.9 percent population increase. Based on the most recent estimates at the time this HMP was updated, it is estimated that Guam has a current population of 165,404. U.S. Census data for 2000 and 2010 indicates varied population growth across Guam with a greater than 10 percent increase in Chalan Pago-Ordot and Mangilao, Mongmong-Toto-Maite and a greater than 10 percent decrease in Agat, Inarajan, Merizo, Piti, Santa Rita, and Umatac.

Dededo, which is geographically one of the largest villages, has the largest population. **Figure D-5** shows the locations of several densely populated areas. Agana Heights, Barrigada, Mangilao, Mongmong-Toto-Maite, Sinajana, and Tamuning/Tumon have areas of dense populations. Most island populations are centered in a geographically narrow point in the approximate center of the island, which is also the largest urbanized area of Guam.

Table 4-1 Population of Guam, 2000–2010

	Population		Change, 2000 – 2010	
Village	**2000**	**2010**	**Number of People**	**% Change**
Agana Heights	3,940	3,808	-132	-3.4
Agat	5,656	4,917	-739	-13.1
Asan/Maina	2,090	2,137	47	2.2
Barrigada	8,652	8,875	223	2.6
Chalan Pago-Ordot	5,923	6,822	899	15.2
Dededo	42,980	44,943	1,963	4.6
Hagatna	1,100	1,051	-49	-4.5
Inarajan	3,052	2,273	-779	-25.5
Mangilao	13,313	15,191	1,878	14.1
Merizo	2,163	1,850	-313	-14.5
Mongmong-Toto-Maite	5,845	6,825	980	16.8
Piti	1,666	1,454	-212	-12.7
Santa Rita	7,500	6,084	-1,416	-18.9
Sinajana	2,853	2,592	-261	-9.1
Talofofo	3,215	3,050	-165	-5.1
Tamuning/Tumon/Tumon	18,012	19,685	1,673	9.3
Umatac	887	782	-105	-11.8
Yigo	19,474	20,539	1,065	5.5
Yona	6,484	6,480	-4	-0.1
Guam (Total)	**154,805**	**159,358**	**4,553**	**2.9**

Source: U.S. Census Bureau 2010.

Young children, the elderly, and people living below the poverty level, all are typically more vulnerable to the effects of hazards. Thus, as of 2010, 14,289 people on Guam, or 9.0 percent of the total population, are 5 years old or younger; 10,747 people, or 6.7 percent of the total population, are 65 years old or older; and 35,803 people, or 22.5 percent of the total population, live below the poverty level. As shown in **Table 4-2**, Umatac has the highest population (11.9 percent) of people under 5 years of any village while Agana Heights, Hagatna and Tamuning/Tumon have the lowest percentage of their total populations that are 5 years or younger of all the villages on Guam (7.8, 7.6, and 7.5 percent respectively). Talofofo highest percentage of total population that is 65 years or older (9.5 percent) and Umatac has the lowest percentages (2.3 percent). Mongmong-Toto-Maite and Umatac have the highest proportion of persons living below the poverty level of any village on Guam (29.7 and 28.8 percent, respectively). Santa Rita has the lowest proportion of the people living below the poverty line (12.9 percent).

Table 4-2 Populations Potentially Vulnerable to Hazards on Guam, 2010

Village	Population			
		Under 5 years	65+ years	Below the 2009 Poverty Level
Agana Heights	3,808	295	313	638
Agat	4,917	466	436	1,305
Asan/Maina	2,137	197	181	400
Barrigada	8,875	736	717	1,787
Chalan Pago-Ordot	6,822	609	445	1,224
Dededo	44,943	4,049	3,252	11,083
Hagatna	1,051	80	56	286
Inarajan	2,273	210	145	404
Mangilao	15,191	1,357	789	3,596
Merizo	1,850	195	138	452
Mongmong-Toto-Maite	6,825	698	427	2,027
Piti	1,454	127	115	241
Santa Rita	6,084	505	370	782
Sinajana	2,592	255	245	502
Talofofo	3,050	282	198	600
Tamuning/Tumon/Tumon	19,685	1,474	1,374	4,466
Umatac	782	93	33	225
Yigo	20,539	1,982	1,123	4,419
Yona	6,480	678	390	1,366
Total	**159,358**	**16,625**	**10,747**	**35,803**

Source: U.S. Census Bureau 2010.

Renters and those living in older homes are typically more vulnerable to the effects of hazards. As shown in **Table 4-3,** renters occupy nearly the same number of homes in Guam than do homeowners. This ratio fluctuates among the different villages. More than twice the number of homes in Hagatna are owner-occupied than renter occupied, but in Mongmong-Toto-Maite about two times as many homes are occupied by renters as by homeowners. **Table 4-3** also shows that most housing units on Guam were built after 1970, with approximately 10.9 percent of the units built before 1970. This ratio also varies by village; only 10.8 percent of the homes in Yigo were built before 1970 while and nearly 90 percent of the homes in Hagatna were built during this same time period.

Table 4-3 Dwelling Units Potentially Vulnerable to Hazards on Guam: Owners/Renters, 2010

Village	Occupied Housing		Housing Units	
	Owner-Occupied	Renter-Occupied	Total	Built <1970
Agana Heights	574	522	1,261	275
Agat	663	596	1,508	194
Asan/Maina	357	282	751	149
Barrigada	1,421	832	2,650	267
Chalan Pago-Ordot	1,213	639	1,852	141
Dededo	11,028	6,034	4,994	1,130
Hagatna	210	76	286	257
Inarajan	130	404	534	53
Mangilao	1,890	1,984	3,874	742
Merizo	252	153	405	43
Mongmong-Toto-Maite	635	1,253	1,938	218
Piti	241	204	445	71
Santa Rita	662	786	1,448	276
Sinajana	404	348	752	137
Talofofo	558	223	781	79
Tamuning/Tumon/Tumon	6,670	2,352	6,670	586
Umatac	171	20	191	25
Yigo	4,960	927	5,887	639
Yona	1,635	297	1,932	131
Guam (Total)	**21,140**	**20,886**	**42,026**	**4,621**

Note: Homeownership represents homeowner- and renter-occupied units, but does not include vacant units. Total housing units represents all housing units, including unoccupied units.
Source: U.S. Census Bureau 2010.

Census 2010 data is used in the 2019 Guam Hazard Mitigation Plan (HMP) planning and development process. The next U.S. Census Bureau survey has been scheduled for 2020. This survey is a method of collecting and analyzing social, economic, and geographic data. It provides information about the conditions of the United States, states/territories, and counties. The resulting data will be timely for the next Guam HMP update planned for 2024.

4.6 ECONOMY

According to the U.S. Census, in 2010 there were a total of 63,678 civilians 16 years and older employed in Guam. As shown in **Table 4-4**, the largest industry (11,081) is the arts, entertainment, recreation, accommodation, and food services industry which mainly supports the 1 million-plus tourists visiting the island each year. Other key industry in Guam includes: educational services, health care and social services (9,748); retail trade (8,305); and construction (7,364).

Table 4-4 Number of Civilians Employed on Guam by Industrial Division, 2010

Industry Description	Number of Paid Employees
Agriculture, Forestry, Fishing, Hunting, Mining	204
Construction	7,364
Manufacturing	1,525
Wholesale Trade	1,878
Retail Trade	8,305
Transportation, Warehousing, Utilities	4,859
Information	1,645
Finance, Insurance, Real Estate, Rental, Leasing	3,489
Professional, Scientific Services, Technical Services	5,651
Educational Services, Health Care, Social Assistance	9,748
Arts, Entertainment, Recreation, Accommodation, Food Services	11,081
Other Services	2,267
Public Administration	5,662
Total	**63,678**

Source: U.S. Census Bureau 2010.

4.7 TOURISM

Table 4-5 shows the annual number of tourists that have arrived in Guam every year from 2000 to 2018. Between 2000 and 2018, 2.36 percent of persons visiting Guam were members of the military. During this period, Guam averaged 1,255,896 tourists annually. Tourist arrivals were highest in 2016, 2017, and 2018. From 2000 to 2018, 98.17 percent of all tourists and military arrived on Guam by air. Civilian tourists typically come from Japan, the U.S. mainland, Hawaii, the Commonwealth of the Northern Mariana Islands (CNMI), Taiwan, Philippines, Korea, Russia and Hong Kong.

Table 4-5 Tourist Arrivals to Guam, 2000–2018

Year	Civilian					Military			Total
	Air								
	Domestic (U.S. Mainland & Hawaii)*	International Air Arrivals	Total Civilian Air Arrivals	Sea Arrivals	Subtotal: Civilian Arrivals	Air Arrivals	Sea Arrivals	Subtotal: Military Arrivals	
2000	41,075	1,243,566	1,284,641	5,987	1,290,628	589	1,577	2,166	1,292,794
2001	38,557	1,101,437	1,139,994	19,114	1,159,108	3,318	16,583	19,901	1,179,009
2002	33,233	1,025,391	1,058,624	5,022	1,063,646	8,288	22,521	30,809	1,094,455
2003	35,409	874,097	909,506	2,411	911,917	5,816	49,663	55,479	967,396
2004	40,563	1,064,086	1,104,649	5,982	1,110,631	7,582	37,986	45,568	1,156,199
2005	41,580	1,115,133	1,156,713	2,605	1,159,318	8,436	42,393	50,829	1,210,147
2006	39,576	1,143,715	1,183,291	2,341	1,185,632	6,600	24,879	31,479	1,217,111
2007	49,590	1,125,972	1,175,562	2,139	1,177,701	9,335	40,380	49,715	1,227,416
2008	52,797	1,031,728	1,084,525	3,203	1,087,728	10,999	32,462	43,461	1,131,189
2009	55,525	978,883	1,034,408	7,264	1,041,672	10,083	1,116	11,199	1,052,871
2010	61,381	1,113,655	1,175,036	8,256	1,183,292	12,696	436	13,132	1,196,424
2011	49,562	1,073,359	1,122,921	7,937	1,130,858	15,502	774	16,276	1,147,134
2012	50,967	1,189,053	1,240,020	4,847	1,244,867	21,615	3,679	25,294	1,270,161
2013	47,058	1,266,218	1,313,276	6,846	1,320,122	17,211	332	17,543	1,337,665
2014	54,459	1,254,866	1,309,325	4,669	1,313,994	21,396	7,702	29,098	1,343,092
2015	58,531	1,324,337	1,382,868	5,284	1,388,152	17,529	3,369	20,898	1,409,050
2016	52,310	1,445,872	1,498,182	2,694	1,500,876	19,250	15,392	34,642	1,535,518
2017	55,625	1,451,781	1,507,406	5,633	1,513,039	14,945	17,408	32,353	1,545,392
2018	80,628	1,432,654	1,513,282	3,238	1,516,520	19,130	13,357	32,487	1,549,007
Average Tourist Arrivals to Guam: 2000–2018									**1,255,896**

Source: Guam Visitors Bureau 2019

4.8 ASSETS

The FEMA software Hazards United States (HAZUS) identifies the following five major categories of critical infrastructure: Essential Facilities, Lifeline (Major) Utilities, Transportation Systems, High Potential Loss Facilities, and Hazardous Material Facilities. **Table 4-6** identifies the critical assets in this plan.

Table 4-6 Essential Facilities, Major Utilities, and Transportation Systems

Essential Facilities	Major Utilities	Transportation Systems
Fire Stations	Electric Power Utilities: - Facilities - Substations - Power Plants - Power Stations	Municipal Airports
Police Stations		Port Facilities
Senior Centers		Traffic Signals
Community Centers		Pedestrian Crossing Signals
Historic Sites		Bridges
Cemeteries and Burial Grounds	Potable Water Systems: - Production Wells - Enclosed Storage Facilities - Storage Basins - Pump Stations - Treatment Plants	Bus SubStations
Parks, Preserves, and Beaches		Major Roads
Recreation Facilities		
Governor's Complex		
Government of Guam Agencies and Departments		
Libraries		
Mayor's Councils of Guam Facilities	Wastewater Systems: - Pump Stations - Treatment Plants	
Health Care Facilities and Clinics		
Public Schools		
Resorts, Hotels, and Motels		

Source: FEMA 2008.

High Potential Loss Facilities, which includes military facilities, nuclear facilities, and dams, are excluded from analysis for a number of reasons: the military bases are federal facilities and outside the jurisdiction of the Government of Guam; for security reasons, detailed information on military facilities is generally not available; and the only dam on Guam (Fena Dam) is also a federal facility and outside the jurisdiction of the Government of Guam. In addition, Hazardous Material Facilities are excluded from this plan are not under the direct control of the Government of Guam. Also, to maintain the focus on critical infrastructure, only major roads (not minor roads) are considered in the 2019 Guam HMP (as was the case in the earlier versions of the HMP).

Despite these exceptions, 823 Essential Facilities, Major Utilities, and Transportation Systems (EFMUTS) owned and operated by the Government of Guam as well as the private sector were identified and geocoded for both the 2014 and 2019 Guam HMP. Values for the EFMUTS were collected from a wide variety of sources, including the following: the Government of Guam agencies that own, operate, and/or insure or maintain the facilities; the Guam Department of Revenue and Taxation; and HAZUS.

For the 2014 and 2019 Guam HMP update, 7 additional EFMUTS (senior centers) were identified for inclusion. These senior centers were not geocoded and are not included in the plan's vulnerability analysis. However, they are listed in **Appendix E** (Essential Facilities, Major Utilities, and Transportation Systems) and will be geocoded and added to the EFMUTs list for the next THIRA or Guam HMP update (see **Section 6.5** [Mitigation Actions] for additional information).

The following is a breakdown of these EFMUTS by major category of Critical Buildings, Facilities, and Infrastructure:

- 348 Essential Facilities worth $903.5 million
- 361 Major Utilities worth $883.6 million
- 114 Transportation Systems worth $110.8 million

Specific EFMUTS are identified in **Tables E-1, E-2, E-3, and E-4** (**Appendix E** [Essential Facilities, Major Utilities, and Transportation Systems]) and are shown on **Figures D-6 through D-11.** These facilities and related data have been mapped using GIS and form the basis for the vulnerability analysis estimates.

4.9 PLANNING AND DEVELOPMENT

4.9.1 General Building Stock

Guam's General Building Stock (GBS) includes 40,069 mapped residential and non-residential buildings. For the updated 2019 Guam HMP, only 2017 new data on building stock or building values was available. Similar to the asset data, GHS/OCD plans to work with relevant Government of Guam agencies during the next THIRA and Guam HMP update process to collect, update, map, and analyze updated GBS data.

For the 2019 Guam HMP, 2010 property tax values were obtained for the average assessed building value (in $/building) for each village. The average building values for Guam's GBS varied from a low of $65,548/building in Umatac to a high of $412,678/building in Tamuning/Tumon. The average value of a building (residential and nonresidential) in Guam is $133,946.

As shown on **Figure D-12** and listed by village in **Tables F-1 and F-2** the highest numbers of buildings, in descending order, are found in the villages of Dededo, Yigo, and Tamuning/Tumon/Tumon. The highest concentrations of building values, in descending order, are found in the villages of Dededo, Tamuning/Tumon/Tumon, and Yigo.

This GBS has been mapped using GIS and has formed the basis for the exposure analysis estimates. However, additional information that would have contributed considerably to the vulnerability analysis results was simply not comprehensively available for the GBS for this update with the time and resources available. Useful information for future plan updates would include the type of building (e.g., residential, commercial, industrial, governmental); age/year built; primary building material; roofing material; general condition; mitigation upgrades (e.g., seismic retrofit, wind shutters); and prior hazard damage.

A method of determining the level of growth in the GBS is through an analysis of building permits. **Table 4-7** shows the numbers of new building permits issued, the total values of these buildings, the number of permits issued for additions to buildings, and the values of these building additions for the years 2000 through 2013. From 2000 to 2013, the largest number of building permits (for both new structures and additions) was issued in 2000.

Table 4-7 Building Permits Issued by Year, 2000–2018

Fiscal Year	Number (New)	Value ($)	Number (Additions)	Value ($)
2000	428	$64,385,684	228	$43,010,412
2001	277	$55,883,125	229	$30,344,695
2002	211	$25,617,000	206	$24,677,000
2003	407	$43,852,733	759	$52,188,523
2004	266	$46,524,605.41	391	$31,112,423
2005	290	$54,521,457	252	$32,288,113
2006	329	$85,383,295	234	$36,971,347
2007	373	$160,096,000	247	$25,807,000
2008	383	$121,840,000	277	$20,835,000
2009	274	$138,662,000	225	$13,050,000
2010	386	$80,501,000	196	$11,157,000
2011	210	$40,455,191	110	$4,947,606
2012	224	$35,732,376	93	$4,406,273
2013	303	$51,628,139	87	$4,019,248
2014	265	$142,824,537	138	$17,611,182
2015	249	$119,380,122	118	$26,411,164
2016	312	$215,500,502	74	$10,647,783
2017	300	$82,496,723	121	$10,220,117
2018	272	$119,153,056	88	$15,204,689

Note: Values do not include government, demolition, relocation, grading, signing, miscellaneous, or renewal permits.

Source: DPW 2019.

Table 4-8 shows the number of building permits issued by village on Guam in 2018. These quantities indicate the villages where large amounts of construction are occurring. Most of the new construction permits issued were for Dededo where 76 permits (28.0%) were issued. The village with the second-highest number of permits issued for new construction in 2018 was Yigo where 58 permits (21.3%) were issued. In 2018, the largest number of permits issued for additions to existing structures was Tamuning-Tumon where 20 permits (23.0%) were issued. Dededo is follows where 17 permits (19.1%) were issued for additions.

Table 4-8 Building Permits Issued by Village, 2018

Village	Permits for New		Permits for Addition	
	Number	Percent of Total	Number	Percent of Total
Hagåtña	4	1.5%	2	2.3%
Agana Hts	1	0.4%	2	2.3%
Agat	4	1.5%	3	3.4%
Asan Maina	4	1.5%	0	0%
Barrigada	21	7.7%	13	14.8%
Chn Pago Ordot	17	6.3%	3	3.4%
Dededo	76	28.0%	17	19.1%
Inarajan	2	0.4%	0	0%
Mangilao	38	14.0%	8	9.0%
Merizo	0	0%	0	0%
M-T-M	5	1.8%	2	2.3%
Piti	2	0.4%	0	0%
Santa Rita	3	1.1%	0	0%
Sinajana	1	0.4%	3	3.4%
Talofofo	17	6.2%	3	3.4%
Tamuning Tumon	11	4.0%	20	23.0%
Umatac	0	0%	0	0%
Yigo	58	21.3%	6	6.8%
Yona	8	2.9%	6	6.8%
Total	**272**	**100%**	**88**	**100%**

Note: Values indicated do not include government, demolition, relocation, grading, sign, miscellaneous, or renewal permits.

Source: DPW 2019.

4.9.2 Military Buildup

The military's 2012 Roadmap Adjustments for the buildup on Guam outlines smaller population growth. The program originally intended to increase the number of military personnel on the island from 6,420 to approximately 18,930 and the number of military dependents from 7,690 to some 19,140. The military initiated this program in May 2006 and initially expected construction to be completed in 2014.

Under the new plan, 5,000 Marines with approximately 1,300 dependents would relocate from Okinawa, Japan and elsewhere to Guam. As part of a larger realignment of U.S. military forces in the Asia-Pacific region, Marine housing would be built within a new base in Dededo—Camp Blaz. In addition, the proposed live-fire training site would be at Northwest Field in Yigo (Anderson Airforce Base) rather than private/government land near Pagat. Buildup construction has been revised to take place over a 13-year period (rather than the original 7-year period planned). The first large group of Marines, however, are not expected on Guam until 2025, and the next two years thereafter for others to gradually transfer.

With the U.S. President's emergency declaration in early 2019, it causes a $749 million setback. Ten percent of the Department of Defense funding for the buildup is proposed to be allocated to U.S.-Mexico border wall.

Skilled workers also delays the process. With President Trump's decision to ban foreign workers, it stifles the skilled workforce to less than 400 locally. Under a thousand skilled workers are still needed.

5.1 PURPOSE

The purpose of this section is to identify and screen the hazards that can affect Guam, profile the hazards selected by the HMAC, inventory the EFMUTS, GBS, and population on Guam, and assess the vulnerability and potential losses to the assets from the qualifiable hazards addressed in the 2019 Guam HMP. This effort builds on data acquired for the earlier versions of the Guam HMP and subsequent data and analyses provided for this 2019 Guam HMP. The information presented and analyzed was the best available data during the 2019 Guam HMP update process.

The following DMA 2000 requirement for the risk assessment does not apply to Guam because the Government of Guam is the only direct grant recipient on Guam.

- Assessing Vulnerability by Jurisdiction (Requirement § 201.4[c][2][ii][Elements A and C])

5.2 IDENTIFY AND SCREEN HAZARDS

The first step in the risk assessment process is the identification and screening of hazards affecting people and property on Guam. The hazards include a range of both natural and man-made hazards that may have occurred in the past and those likely to occur in the future (even if they have not occurred in the past).

The DMA 2000 hazard identification requirements are shown below and addressed in the following text.

DMA 2000 REQUIREMENTS – RISK ASSESSMENT – IDENTIFYING HAZARDS
Identifying Hazards Requirement § 201.4(c)(2)(i): *[The State risk assessment **shall** include an] overview of the type of all natural hazards that can affect the State.*
Element A. Does the new or updated plan provide a description of the type of **all natural hazards** that can affect the State? If the hazard identification omits (without explanation) any hazards commonly recognized as threats to the State, this part of the plan cannot receive a Satisfactory score? Source: FEMA 2008.

A summary of the hazards that can affect Guam are shown in **Table 5-1**. This table was originally created for the 2005 Guam HMP and the historical hazard information has been updated with each Guam HMP update. With subsequent versions of the plan, additional hazards have been included in **Table 5-1**. During the 2019 Guam HMP update, the HMAC thought it important not only to address hazards that have created major issues to date, but also to include potential hazards (i.e., hazards that can be foreseen as becoming issues in the future). As such, for this plan update, non-seismic ground failure hazards (sinkholes), slope failure (non-seismic landslide, mudslide, and post-fire debris flow), and terrorism were included. In addition, during this update, the HMAC also decided to reclassify some subhazards as hazards. The following hazards were profiled in previous plans as subhazards, but are profiled as major hazards starting in the 2011 Guam HMP: coastal erosion, flooding, high surf, salt spray, severe wind, and tsunami. Also, what was previously labeled as seismic hazard is now titled earthquake and includes surface fault rupture, liquefaction, and lateral spread.

In 2014, the GHMO announced at the HMAC meeting that climate change needed to be identified in the 2014 Guam HMP to address the President's Executive Order to prepare the United States for the impacts of climate change. Since the existing Guam HMP already addresses many impacts of climate change, including coastal erosion (**Section 5.3.1**), drought (**Section 5.3.3**), flooding (**Section 5.3.5**), and wildland fire (**Section 5.3.17**), the HMAC determined that only sea level rise is needed to be addressed in the 2014 and 2019 Guam HMP.

As shown in **Table 5-1**, efforts were made to avoid the double-counting of events by aggregating them into a primary hazard event. For example, a tropical cyclone/typhoon accompanied by severe wind and flooding was entered only once under tropical cyclone/typhoon, though the multiple subhazards were noted in the description of the event. Also, information regarding fatalities, injuries, and property damage was available for only a small proportion of the hazard events. In most cases, this information should not be considered an accurate representation of the potential damage experienced to date.

Table 5-1 Summary of Historical Record of Hazards on Guam

Hazard	Historical Records						Further Evaluation/Major Hazard Category
	Number of Records			Recorded Damages			
	Disaster/ Emergency Declarations	Other Significant Events	Total	Fatalities	Injuries	Losses ($)	
Climate Change	0	3	0	0	0	0	Sea Level Rise [Coral Bleaching/ Increased Sea Surface Temperature/ Ocean Acidification]
Coastal Erosion	0	5	5	N/A	N/A	N/A	Coastal Erosion [Sea Level Rise]
Dam Failure	0	0	0	0	0	$0	No further consideration
Disease	0	6	6	4,080	0	N/A	Disease
Drought	0	7	7	0	0	$0	Drought
Earthquake	1	38	39	0	61	$1,000,000 + Royal Palm damage	Earthquake
Expansive Soil	N/A	N/A	N/A	N/A	N/A	N/A	No further consideration
Extreme Heat	0	0	0	0	0	$0	No further consideration
Fissure	0	0	0	0	0	$0	No further consideration
Flood	0	8	8	1	1	$6,500,000	Flood
Fog	0	0	0	0	0	$0	No further consideration
Hail	0	0	0	0	0	$0	No further consideration
Hazardous Materials	0	11	11	0	0	N/A	Hazardous Materials
High Surf	0	7	0	35	41	$4,000,000	High Surf
Landslide	0	7	7	N/A	N/A	N/A	Slope Failure

Table 5-1 Summary of Historical Record of Hazards on Guam

Hazard	Historical Records						Further Evaluation/Major Hazard Category
	Number of Records			Recorded Damages			
	Disaster/ Emergency Declarations	Other Significant Events	Total	Fatalities	Injuries	Losses ($)	
Lightning	0	18	18	2	0	$405,000	Lightning
Liquefaction	0	1	1	N/A	N/A	$8,000,000	Earthquake
Mudslide	0	N/A	N/A	N/A	N/A	N/A	Slope Failure
Nuclear Incident	0	0	0	0	0	$0	No further consideration
Post-fire Debris Flow	0	N/A	N/A	N/A	N/A	N/A	Slope Failure
Salt Spray	0	11	11	N/A	N/A	N/A	Salt Spray
Severe Wind	0	24	24	N/A	3	$775,000	Severe Wind
Sinkholes	0	N/A	N/A	N/A	N/A	N/A	Non-Seismic
Subsidence	0	0	0	0	0	$0	No further consideration
Terrorism	0	0	0	0	0	$0	Terrorism
Thunderstorm	0	0	0	0	0	$0	No further consideration
Tornado	0	6	6	0	0	N/A	No further consideration
Tsunami	0	12	12	0	0	N/A	Tsunami
Transportation Accident	1	1	2	225	0	N/A	Transportation Accident
Tropical Cyclone/ Typhoon	15	199	222	86	461	$2,047,408,640	Tropical Cyclone/Typhoon
Volcano	0	0	0	0	0	$0	No further consideration
Wildland Fire	1	5	6	0	1	$250,000	Wildland Fire

Note: "Declarations" refers to Presidentially declared disasters or emergencies. The hazard event database covers the period 1971 to July 2019, though approximately 90 percent of the records are from 1970 to the present. Information on fatalities, injuries, and property damage is available for only a small proportion of the total number of records and should be considered incomplete.

N/A = not available
Sources: FEMA 2019; Guam Power Authority 2019; NWS-WFO Guam 2019; NTSB 2004b; GHS/OCD 2019; National Response Center 2019; USGS 2019; NCDC 2014.

For the 2019 Guam HMP update, the GHMO and HMAC reviewed the hazards selected during the previous plan updates. These hazards were selected based on the following:

- Results of the historical hazard event database
- Expert opinion of the risk presented by the hazards
- Ability to mitigate the hazard through the DMA 2000 process
- The known or expected availability of information on the hazard

Based on their review, the HMAC decided to keep the hazards previously profiled and also include sea level rise as a new hazard. As such, the following hazards are profiled in the 2014 and 2019 Guam HMP.

Table 5-2 Hazards Profiled in the 2014 and 2019 Guam HMP

Hazard Categories	
Coastal Erosion	Salt Spray
Disease	Sea Level Rise
Drought	Severe Wind
Earthquake: Surface Fault Rupture, Liquefaction, Lateral Spread	Slope Failure: Landslide, Mudslide, Post-Fire Debris Flow
Flooding: Coastal Flooding, Riverine Flooding, Stormwater Runoff	Terrorism
Hazardous Materials	Transportation Accident
High Surf	Tropical Cyclone
Lightning	Tsunami
Non-Seismic Ground Failure/Sinkholes	Wildfire

5.3 HAZARD PROFILES

The DMA 2000 profiling hazard requirements are shown below and addressed in the following text.

DMA 2000 REQUIREMENTS – RISK ASSESSMENT – PROFILING HAZARDS

Profiling Hazards

Requirement § 201.4(c)(2)(i): *[The State risk assessment **shall** include an overview of the] location of all natural hazards that can affect the State, including information on previous occurrences of hazard events, as well as the probability of future hazard events, using maps where appropriate.*

Element

A. Does the risk assessment identify the **location** (i.e., geographic area affected) of each natural hazard addressed in the new or updated plan?
B. Does the new or updated plan provide information on **previous occurrences** of each hazard addressed in the plan?
C. Does the new or updated plan include the probability of **future events** (i.e., chance of occurrence) for each hazard addressed in the plan?

Source: FEMA 2008.

The hazards selected for profiling were analyzed in 2004–2005, updated in 2008, 2011, 2014, and are again updated in 2019; each hazard was analyzed in a methodical manner based on the following four categories: nature, location, previous occurrences, and probability of future events.

5.3.1 Coastal Erosion

Nature

Coastal erosion can be described as the horizontal retreat of the shoreline. It is a part of a larger process of shoreline change that includes erosion and accretion, except along coastal cliffs. Coastal erosion is the movement of sediment from the shoreline into the ocean. Accretion is the movement of sediment onto a shoreline from the ocean. Many shorelines experience both erosion and accretion. If a balance of these two processes occurs, the shoreline is considered to be stable. Coastal cliffs generally erode in the form of a landslide into the ocean. Coastal cliffs cannot experience accretion. Many community reports raise the concern that the beach profile is in not accreting and that there is a constant erosion rate along many of our coastline.

Due to the potential cycles of erosion and accretion, coastal erosion is generally quantified over several years. Coastal erosion is measured as a rate, expressed either as a linear length of retreat compared to time or as a volumetric loss compared to time.

Coastal erosion on Guam can be caused by winds; ocean currents; storm surges; high surf; seismic activity; changes in the geometry of tidal inlets, river outlets, and bay entrances; man-made structures and human activities, such as shore protection structures and dredging; and/or local scour around structures. La Niña and El Niño events also contribute, with El Niño causing lower sea levels but increased tropical cyclone activity, while La Niña causes less tropical cyclone activity, but higher background sea levels. In addition, sea level rise has an effect on coastal erosion. Sea levels appear to have risen about 8 inches over the last century, with greater rises over the last two decades.

Human-built structures, such as properly engineered shore protection structures, can greatly increase the rate of coastal erosion in adjacent properties that are not armored, while preventing any beach profile to accrete parallel to the wall. . Cleared areas that are exposed to prevalent winds and open ocean waves often have a higher potential to experience heavy coastal erosion than highly vegetated areas where structures are set-back father inland. The erosion of coastal cliffs can threaten the safety of land uses at the top of the cliffs. Coastal erosion can lead to sediment transport onto nearby reefs, which can lead to the decline of the health of these reefs.

Location

The entire coastline of Guam has the potential for coastal erosion hazards. The western coast of Guam has experienced the most coastal erosion to date due to tropical cyclones and monsoon surges that have produced high waves.

Previous Occurrences

No disaster has been declared on Guam due to coastal erosion. No comprehensive documentation is available regarding coastal erosion on Guam, and damage estimates due to coastal erosion have never been specifically reported. As illustrated by the above discussion of the causes of coastal erosion, coastal erosion is almost always associated with another hazard. Many large tropical cyclones have made landfall on Guam or have come close to making landfall. These storms all have resulted in storm surges, high surf, and high winds, all of which are key causes of coastal erosion. However, available historical records describe coastal erosion occurrences for only a few storms. Therefore, it is probable that incidences that have caused coastal erosion have been severely underreported.

Typhoon Andy in 1982, Typhoon Dale in 1996, Typhoon Halong in 2002, and Super Typhoon Pongsona in 2002 were all documented to have caused coastal erosion. No specific details are available about the locations of coastal erosion for Typhoon Andy. Typhoon Dale contributed to high surf for several days, resulting in large areas of coastal erosion along beaches on the western side of the island. The high surf and storm surge caused by Typhoon Halong led to erosion along the island’s southeast shorelines. Super Typhoon Pongsona caused coastal erosion on the western side of the island, which washed out a few stretches of road and blocked several stretches of road with rubble and sand.

The west side of Guam is impacted is impacted from typhoons and monsoon activity often associated with El Nino events. East side erosion occurs from typhoons and from elevated sea levels due to La Nina events.

Vulnerable assets include the coastal trees, beaches, coastal soil, and some near-shore infrastructure such as highways, buried cables, and sewer pump stations.

Vulnerable jurisdictions include all coastal areas that are non-cliff areas. This would be from Mangilao on the northeast, clockwise around the east, through the south, through the west to Agat. Then from Piti clockwise to Gun Beach and from Tanguisson clockwise through Arunao, to Ritidian Point through the northern beaches.

Climate change threatens coastal areas, which are already stressed by human activity, pollution, invasive species, and storms. Sea level rise could erode and inundate coastal ecosystems and eliminate wetlands. Warmer and more acidic oceans are likely to disrupt coastal and marine ecosystems on Guam.

Probability of Future Events

Because various factors contribute to coastal erosion events and given the general lack of data regarding erosion rates, the return rate for coastal erosion is unknown. However, high surf and storm surge caused by tropical storms and typhoons can result in coastal erosion. On average, three tropical storms and one typhoon pass within 180 nautical miles of Guam each year.

The Guam Coastal Management program conducted a study called An Aerial Analysis of Shoreline Variability along the Western Shore of Guam. Erosion rates varied in areas studied by However most of the following areas studied experienced erosion. In some areas, residence of the area claim the erosion rates are much higher.

- Anigua - erosion rate is erosion rate estimated at 6-inches a year.
- Adelup Point - erosion rate estimated at 1.5 inches a year.
- Fish Eye - negligible amount of erosion
- Apaca Point - erosion rate of 50 inches a year
- Gaan Point -erosion rate of rate of 7 inches a year.
- Taelayag Beach - erosion in this area is negligible
- Sagua Beach - erosion rate estimated at 23-inches a year

Erosion remains highly probable in the future. The Honolulu District of the U.S. Army Corps of Engineers (USACE), at the request of Government of Guam Bureau of Statistics and Plans (Gov. Guam), has conducted the first of a two phase regional study of the Agat shoreline located on the Island of Guam to identify areas of significant shoreline erosion, determine the causes of the erosion, and investigate various modifications to Agat Small Boat Harbor to address issues experienced by harbor users. Phase 2 will consist of development of conceptual plans for shoreline stabilization within the study region. This study is being accomplished in accordance with the Planning Assistance to States agreement executed between the Commonwealth of the

Northern Mariana Islands and the U.S. Army Corps of Engineers, Honolulu District and Section 22 of the Water Resourced Development Act of 1974 (Public Law 93-251, as amended).

5.3.2 Disease

Nature

A disease is a pathological (unhealthy or ill) condition of a living organism or part of the organism that is characterized by an identifiable group of symptoms or signs. Disease can affect any living organism, including people, animals, and plants. Disease affects people, animals, and plants both directly (through infection) and indirectly (through secondary effects). Some diseases can directly affect both people and animals. For this risk assessment, the major concern with respect to disease is an epidemic, a disease that affects numerous people, animals, or plants at one time.

Epidemics are generally identified by the infectious diseases involved. Infectious diseases are caused by the entry and growth of microorganisms within another living organism. Most, but not all, infectious diseases are contagious, that is, communicable to an organism through (1) direct or indirect contact with another organism infected with the disease, (2) something the organism has touched that contains the disease, or (3) another medium containing the disease (e.g., water or air).

Infectious diseases are the leading cause of death in humans worldwide and the third leading cause of death in humans in the U.S. A report from the Institute of Medicine titled *Microbial Threats to Health: Emergence, Detection, and Response* notes that the impact of infectious diseases on the U.S. has grown in the last 10 years and that the public health and medical communities remain inadequately prepared.

The Centers for Disease Control and Prevention (CDC) has established a list of over 50 nationally notifiable diseases. A notifiable disease is one that, when diagnosed, health providers are required to report to state or local public health officials. Notifiable diseases are those of public interest by reason of their contagiousness, severity, or frequency. The long list includes such diseases as the following: AIDS; anthrax; botulism; cholera; diphtheria; encephalitis; gonorrhea; hantavirus pulmonary syndrome; hepatitis (A, B, C); HIV (pediatric); Legionellosis; Lyme disease; malaria; measles; mumps; plague; polio (paralytic); rabies (animal and human); Rocky Mountain spotted fever; rubella (also congenital); salmonellosis; SARS; streptococcal disease (Group A); streptococcal toxic-shock syndrome; *Streptococcus pneumoniae* (drug resistant); syphilis (also congenital); tetanus; toxic-shock syndrome; trichinosis, tuberculosis, typhoid fever; and yellow fever.

In addition to diseases that occur only in humans, there also is significant concern about diseases that affect both humans and animals, known as zoonotic diseases. Approximately 40 zoonotic diseases are known to exist, including rabies, tuberculosis and brucellosis, trichinosis, ringworm, giardiasis, and Lyme disease.

In Guam, the Department of Public Health and Social Services (DPHSS) seeks to prevent infectious diseases from entering the island and to control those that are endemic or have already entered. Of particular concern to DPHSS are new pandemic diseases, such as SARS, new strains of HIV, new influenza strains, botulism, and bio-terrorism incidents such as anthrax, small pox, or chemical attacks of sarin or VX gas. DPHSS monitors and controls more than 70 infectious diseases of public health concern such as measles, rubella, pertussis, hepatitis B, and various gastrointestinal diseases.

Diseases affecting animals and plants, particularly livestock and agricultural products, are also of major concern. According to the National Animal Health Emergency Management System, an animal health emergency is defined as the appearance of disease with the potential for a sudden negative impact through direct impact on productivity, real or perceived risk to public health, or real or perceived risk to a foreign country that imports livestock and agricultural products from the United States.

A division of the USDA, the Animal and Plant Health Inspection Service (APHIS), is responsible for protecting and promoting U.S. agricultural health, administering the Animal Welfare Act, and carrying out wildlife damage management activities. Major programs within APHIS relating to disease are Veterinary Services (VS) and Plant Protection and Quarantine. Both types of programs are discussed below.

VS protects and improves the health, quality, and marketability of animals, animal products, and veterinary biologics by (1) preventing, controlling, and/or eliminating animal diseases and (2) monitoring and promoting animal health and productivity. Among other activities, VS conducts surveillance on national animal diseases, foreign animal diseases, emerging animal diseases, and invasive plant species. Most VS efforts are targeted at diseases on the Organization Internationale des Epizooties (OIE) disease list.

The Plant Protection and Quarantine program, also located within USDA's APHIS, safeguards agriculture and natural resources from the risks associated with the entry, establishment, or spread of animal and plant pests and noxious weeds. Several thousand foreign plant and animal species have become established in the U.S. over the past 200 years, with approximately one in seven becoming invasive. An invasive species is an alien (i.e., nonnative) species whose introduction causes, or is likely to cause, economic or environmental harm or harm to human health. Invasive plants, animals, and pathogens have often reduced the economic productivity and ecological integrity of agriculture, forestry, and other natural resources of the United States.

Invasive species on Guam have severely impacted natural and environmental resources. Common vertebrate invasive species in Guam include the brown tree snake and the musk shrew. Numerous invertebrate invasive species, such as the giant African land snail, predatory flatworm *Platydemus manokwari,* cycad Aulocapsis scale, and coconut rhinoceros beetle (CRB), have recently become established in Guam.

The Guam Department of Agriculture is primarily concerned with plant, livestock, and wild animal diseases and infections. The OIE develops standards and guidelines for use in protecting against incursions of diseases or pathogens during trade in animals and animal products. The concern is with both animal-to-animal diseases as well as diseases transmitted from animals or arthropod vectors to humans.

Many other hazards, such as floods, earthquakes, or droughts, can create conditions that significantly increase the frequency and severity of diseases. These other hazards can affect basic services (e.g., water supply and water quality, wastewater disposal, and electricity), the supply and quality of food, and the capacity of both the public health and the agricultural health system, which can lead to concentrations of diseases and, potentially, large losses of life and economic value.

Since the anthrax attacks that occurred after the attacks of September 11, 2001, the possibility that diseases might be used against humans, animals, or plants has become a growing concern, especially for diseases capable of disrupting the human or animal food chain.

Location

All of Guam and the people residing in Guam are susceptible to diseases. **Table 5-3** presents a detailed breakdown of several of the recent (2017) larger disease outbreaks by months.

On an average, the more highly populated villages, such as Dededo, Yigo, and Tamuning/Tumon/Tumon, have some of the highest number of cases. One thing to note is that the relatively highly populated village of Mangilao has relatively lower numbers of cases than villages with smaller populations, such as Barrigada. The military has relatively large numbers of cases for some of the more highly communicable diseases that cannot be vaccinated against, such as chlamydia and strep throat.

Table 5-3 Guam 2017 Annual Summary of Notifiable Conditions

	Month												
Reported Condition	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**	**Grand Total**
AIDS		1	1		1	1			1				5
Acinetobacter baumanii	6	11	6	5	6	3	1	3	8	4		1	54
Aceptic meningitis							1	3	2		1		7
Bacterial meningitis, other	1	1	1										3
Campylobacteriosis		1		2				3	2	1			9
Chancroid	1										1		2
Chlamydia trachomatis infection	116	92	95	92	77	73	80	91	104	114	99	74	1107
Cholera									1				1
Ciguatera fish poisoning						2							2
Citrobacter freundii									1				1
Clostridium difficille	1		1	3		2	1	1					9
Conjunctivitis, viral or bacterial	10	14	14	24	12	6	1	9	16	10	7	10	133
Dengue							1	1					3
Diptheria												1	1
E.coli other	12	7	15	13	12	4	14	21	13	6	6	4	127
Gonorrhea	21	17	17	12	17	13	21	17	18	20	11	16	200
Haemophilus influenzae, invasive disease				1		1			2				4
Hand, Foot, and Mouth disease					1				2				3
Hansen disease (Leprosy)		2		2	2	2	2	1		1	2		14
Hepatitis A, Acute						1							1
Hepatitis A, Chronic		1					1						2
Hepatitis B, Acute	5	7	5	11	10	10	9	13	4	5	11	19	109
Hepatitis B, Chronic	6	2	6	1	4	6	2	2	1	3	4	5	42

Table 5-3 Guam 2017 Annual Summary of Notifiable Conditions

	Month												
Reported Condition	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**	**Grand Total**
Hepatitis B, perinatal infection	1	1	1	1					1	1			6
Hepatitis C, Acute							1						1
Herpes simplex Type 2	1		3	4	1	4	3	2	2	2			22
HIV infection, adult (>=13 years)		2	1	1	1				2		1		8
Human papillomavirus (HPV)	2	4	6	4	5	2	8	5	2		1	1	40
Influenza, human isolates	52	32	35	12	4			15	169	98	15		15
Klebsiella pneumoniae	3	1	3	5	1	3	2	3	7			6	34
Leptospirosis	2	1							2				5
Meningococcal disease								1					1
Mumps													0
Parvovirus B19 (Fifth Disease)				3					1				4
Pertussis													0
Proteus mirabilis								3	1	2			6
Pseudomonas aerunginosa		1				1	1	3	1				7
Respiratory Syncytial Virus (RSV)	2	1		1			1	3	2	7	3	7	27
Rubella													0
S. aureus, coag+, meth- or oxi- resistant (MRSA)	60	32	55	50	18	30	36	44	64	30	15	14	448
Salmonellosis	4		2	1	1	2	1	4	2			4	21
Scabies		12	2	14	11	11	7	14	18	113	6	4	112
Scarlet fever									1	1			2
Scombroid fish poisoning			2										2
Shigellosis	2	2	1	2	1	2		1	1	2		2	16
Strep. other	23	18	14	23	13	16	16	24	26	17	2	2	194
Streptococcal sore throat	52	68	83	49	68	35	12	31	108	101	22	41	670
Syphillis, early latent			1	1							1		3
Syphillis, late latent			1			1	1		1	1			5
Syphillis, primary	1			1					1	1	1	2	7
Syphillis, secondary		1	1				2			1		1	6
Trichomonas	6	2	7	3	10	4	5	3	6	3	5	2	56
Tubercolosis	12	3	6	5	8	3	8	5	7	11	11	5	84

Table 5-3 Guam 2017 Annual Summary of Notifiable Conditions

Reported Condition	Month												
	January	February	March	April	May	June	July	August	September	October	November	December	Grand Total
Vancomycin-Resistant Enterococcus	2	3	1		2	3							11
Varicella (Chickenpox)					1								1
Varicella infection		2	4	4	7	4	3	1	1	6	5	2	30
Varicella deaths													0
Grand Total	404	342	390	349	294	246	241	327	601	462	229	250	4,135

Source: DPHSS 2018.

Previous Occurrences

Guam has historically suffered from many large outbreaks of diseases. The first recorded disease outbreak on Guam was an influenza epidemic in 1688. In 1856, a smallpox epidemic was recorded that resulted in 3,463 deaths and left only 4,724 residents on the island after the 9-month epidemic. Bacillary dysentery caused 147 deaths from 1924 to 1925. Between 1932 and 1938, measles and whooping cough caused a total of 468 deaths. Several Salmonella outbreaks occurred in the early 1980s, with 203 recorded cases in 1981 and 251 cases in 1984. The village of Inarajan experienced an isolated epidemic of shigellosis, which is an infection of the small intestine associated with poor sanitation, inadequate water supplies, contaminated food, crowded living conditions, and fly-infested environments in 1984, with 90 recorded cases and 2 deaths.

More recently, a large outbreak of measles occurred in 1994, when 228 cases were reported. All of these cases occurred between February and June. Ninety of the cases occurred in children that were less than 1 year of age and 70.6 percent occurred in children between 1 and 5 years of age. Of the 228 cases, 133 (58 percent) occurred among patients who were Chamorros (an ethnic group native to Guam), 45 (20 percent) occurred among persons from the Chuuk State of the Federated States of Micronesia, and 29 (13 percent) among Filipinos. In 2010, a large outbreak of mumps occurred. The 502 cases of mumps recorded in was the highest since 1958 when 1,268 cases were reported. Two cases were associated with visitors from Japan.

Many of the diseases with large numbers of infections are relatively common illnesses that are easily communicable, like influenza, strep throat, and sexually transmitted diseases. There are, however, some particular epidemics noted in **Table 5-4**. In 2006 there were two large outbreaks of food poisoning. The first included a number of students who ate lunch prepared by their elementary school and the second affected a number of Japanese tourists who had eaten at a number of regulated establishments. In 2007 there was a jump in the reported cases for both invasive strep disease and tuberculosis. 14 cases of invasive strep disease were reported in 2007, which is the highest number of cases seen since data collection for this condition was initiated in 1993. In 2007 Guam also experienced the most new cases of tuberculosis reported since 1997, reaching a high of 92 reported cases. This represents a rate of 53 new cases of tuberculosis per 100,000 population, which was 12 times the 2007 U.S. rate. 2007 also saw an extreme increase in the number of the reported influenza cases, at the time this was the highest number of reported cases since 1996, 82.5 percent of which were reported during the months of September through November. However, a second wave of “seasonal” influenza occurred in 2009, when 337 cases were reported, marking a new high.

The first case of brucellosis since 1991 was also reported in 2009. As shown in **Table 5-4**, many small outbreaks of diseases have occurred in recent history. Many of these outbreaks are imported to Guam by temporary travelers who spread their infection on the island and leave without being detected. For instance, the 9 measles cases in 2002 were linked by the CDC to a Japanese tourist who had previously caused a measles outbreak in Palau. Also, in 1992 and 1993 several cases of malaria and typhoid fever were brought to the island from other countries. Three cases of dengue fever were reported in Guam in a 3-week period during February 2008; two cases were contracted in the Philippines and one case was contracted in Bali, Indonesia.

Table 5-4 Summary of Guam Notifiable Disease Case Reports, 2007–2017

Disease	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
AIDS	4	6	2	6	6	7	1	6	3	2	5
Amebiasis			1				1				
Campylobacteriosis	14	8	7	4	9	7	7	5	4	8	9
Chickenpox	239	95	32	28	102	50	57	33	29	19	40
Chlamydia	822	690	655	900	1071	1031	937	793	979	934	1107
Cholera 01 El Tor				1	1			1			1
Conjunctivitis	721	420	458	328	437	316	278	568	306	87	133
Dengue	3*	6*		3*	3*	5*				3*	3*
Fish poisoning (Ciguatera)	2	3			1			2			
Fish poisoning (Scombroid)	4	2		1	6	4	7	1		1	2
Food poisoning	35	18	27		195	20	37	5	2		
Giardiasis	2		3	3		2	2		1		
Gonorrhea	142	113	61	98	96	92	92	99	154	134	200
Hansen’s disease	7	1	6	10	2	10	17	13	22		14
Hepatitis A		7	7	4	43	22	31	22	48	2	3
Hepatitis B	3	20	57	77	120	66	75	56	113	136	157
Hepatitis C	1	10	49	61	70	61	71	71	138	49	1
Herpes simplex, Type 2	10	26	11	20	30	41	37	39	36	31	22
HIV	6	5	4	9	6	11	3	6	11		8
Influenza	194	45	586	23	71	136	92	152	92	268	458
Legionellosis				1							
Leptospirosis	1	1	1		4	3			11		5
Malaria	1*	4*						2	1		
Measles											
Meningitis, aseptic	4	8		1		2	2	4	3		
Meningitis, other or unspecified	2	2	2	3		1	6	6		2	
Meningococcal disease			1				1				1
MRSA	218	252	344	385	565	535	445	369	548	440	448
Mumps	6	3		502	3	3		6	5		

Table 5-4 Summary of Guam Notifiable Disease Case Reports, 2007–2017

Disease	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Pertussis			2	3	7	1		3	31		
Rheumatic fever (active)	3	3		1	5	4		1	2		
Rubella		1			2						
Salmonellosis	20	23	11	11	19	13	18	13	18	21	21
Scabies	19	11	2	8	14	28	89	322	300	163	112
Scarlet Fever	11	5	2	7	12	8	25	5	8	6	2
Shigellosis	19	20	13	5	16	1	7	4	14	14	16
Strep disease, invasive	14	12	15	4	14	13	18	19	2		
Streptococcal sore throat	466	472	325	593	471	328	516	331	451	494	864
Syphilis, all stages	35	44	12	11	26	28	23	9	21	17	21
Syphilis, congenital	2						1	4		1	
Toxoplasmosis				1							
Tuberculosis	92	89	102	101	81	69	48	37	77	74	84
Typhoid Fever											
Vancomycin resis. Enterococcus	8	15	12	28	26	46	36	30	35	11	11
Vibrio cholerae Non-O1	1										
Vibrio parahaemolyticus	1	2	1		1		1				

* Indicates infection was first diagnosed on Guam but acquired elsewhere

Source: DPHSS 2018.

Several cases of zoonotic diseases have been documented on Guam. In 1967 a rabies incident affected 89 animals over a 7-month period. No human infections were reported, but the control measures employed resulted in the elimination of 13,406 dogs on Guam. In the nine-year period of 2000 to 2009, 21 people contracted leptospirosis. Cases have been reported in reference to the Cross-Island Road area, Sigua Falls and Talofofo River. Leptospirosis is a disease caused by exposure to bacteria that can be found in freshwater contaminated by animal urine.

No data are readily available regarding animal disease outbreaks on Guam. However, Guam has experienced large, adverse effects from invasive animal species. The brown tree snake on Guam is often considered an example of how a nonnative species can proliferate and destroy the ecology of an area. This animal is presumed to be responsible for the extinction of several endemic bird and lizard species on Guam and is also responsible for millions of dollars in damage each year by causing power failures throughout Guam. Some of the other large pests introduced to Guam from outside are water buffalo, feral pigs, and deer. The large African land snail and a species of flatworm that was introduced to reduce the population of this snail are both considered invasive pests on Guam. In December 2003, a nonnative insect known as cycad Aulocapsis scale was detected in Guam on an ornamental cycad (a palm-like tree). Over the next 2 years it spread throughout the northern two-thirds of Guam, infesting and killing both ornamental and indigenous cycads. Cycas micronesica, the indigenous cycad unique to Micronesia, seems particularly susceptible, with mortality rates of 100 percent in infested areas and causing it to be added to the Red List of Threatened Species maintained by the International Union for the Conservation of Nature and Natural Resources.

In the fall of 2007, CRB was first detected on Guam at Tumon Bay. This large scarab beetle poses a serious threat to palm trees; adult beetles bore deep into the crowns of coconuts and other palms to feed on sap. Trees are killed when beetles bore through the meristematic tissue and by secondary infection by pathogens. The dead trees then provide breeding sites for future generations of CRBs. An eradication program was implemented, by the Guam Department of Agriculture and the United States Department of Agriculture (USDA) Animal and Plant Health Inspection Services, which established a quarantine area covering over 28,000 acres. As of 2013, new rhino beetle trap design and trainings to help identify CRB damage on palms trees and at breeding sites CRB breeding sites have given reason for hope to eradicate CRBs on Guam.

Probability of Future Events

The probability of a disease, particularly an epidemic, occurring on Guam is difficult to evaluate due to the wide variation in disease characteristics, including variation in the rates of spread, morbidity, and mortality; detection and response time; and the availability of vaccines and other forms of prevention. A review of the historical record (as described above) indicates that disease-related disasters have occurred in humans with some regularity and occasional severity. For example, MRSA appears to have affected approximately 200-500 people on Guam annually, while Leptospirosis in most years only affected one person per year. Due to a lack of historical information, it is difficult to make a similar conclusion for animals and plants. Today, concern is also growing about emerging infectious diseases and the possibility of a bioterrorism attack, although the probability and magnitude of such events cannot be predicted.

5.3.3 Drought

Nature

Drought is a normal part of virtually every climate on the planet, including areas of both high and low rainfall. Drought is different from normal aridity, which is a permanent characteristic of the climate in areas of low rainfall. Drought is the result of a natural decline in the expected precipitation over an extended period-of-time, typically one or more seasons. The severity of a drought can be aggravated by other climatic factors, such as prolonged breezy conditions and low relative humidity.

Drought is a complex natural hazard. This complexity is reflected in the following four definitions commonly used to describe it:

- Meteorological drought is defined solely on the degree of dryness, expressed as a departure of actual precipitation from an expected average or normal amount based on monthly, seasonal, or annual time scales.
- Hydrological drought is related to the effects of precipitation shortfalls on stream flows and reservoir, lake, and groundwater levels.
- Agricultural drought is defined principally in terms of soil moisture deficiencies relative to water demands of plant life, usually crops.
- Socioeconomic drought associates the supply and demand of economic goods or services with elements of meteorological, hydrologic, and agricultural drought. Socioeconomic drought occurs when the demand for water exceeds the supply as a result of weather-related supply shortfall. This type of drought is also called a water management drought.

A drought's severity depends on numerous factors, including duration, intensity, geographic extent, the regional water supply capacity/resources, and the demands of humans and vegetation. Due to its multidimensional nature, drought is difficult to define and poses difficulties in terms of comprehensive risk assessments.

Drought differs from other natural hazards in three ways. First, the onset and end of a drought are difficult to determine due to the slow accumulation and lingering effects of an event after its apparent end. Second, the lack of an exact and universally accepted definition of drought adds to the confusion about its existence and severity. Third, in contrast to other natural hazards, the impact of drought is not always obvious and may be spread over a large geographic area. These characteristics hinder the preparation of drought contingency or mitigation plans by many governments.

Drought can cause a shortage of water for human and industrial consumption, hydroelectric power, recreation, and navigation. Water quality can also decline, and the number and severity of wildland fires can increase. A severe drought can result in the loss of agricultural crops and forest products, undernourished wildlife and livestock, lower land values, and higher unemployment.

The US Drought Monitor (USDM) also provides classifications for the western North Pacific Micronesian islands. These are D0-abnormally dry, D1-moderate drought, D2-Severe Drought, D3-Extreme Drought, and D4-Exceptional Drought. These can be further be classified as Short-term, less than 6 months, or Long-term, more than 6 months. Further information on the US Drought Monitor can be found at https://droughtmonitor.unl.edu/. The USDM evaluates drought based on rainfall criteria derived from meteorological drought, agricultural drought, and sociological drought for the Pacific Islands. This criteria was determined through meetings among a Weather Forecast Office (WFO) Guam scientist, a Water and Environmental Research Institute of the Western Pacific at the University of Guam scientist, and the USDM.

Location

The entire island is susceptible to drought.

Previous Occurrences

A review of the monthly rainfall data from the Western Regional Climate Center for the weather station at Tiyan indicated that meteorological droughts may also have occurred in 1950/1951/1952/1953, 1959, 1965/1966, 1973, and 1975. In more recent years, the Government of Guam has recognized droughts immediately following an El Niño cycle in 1973, 1977, 1983, 1987, 1993, 1998, 2016, and 2019. The Weather Forecast Office in Guam characterizes the following years as drought years for Guam, based on four consecutive or more months of less than 4 inches of rain: 1950, 1952, 1953, 1959, 1960, 1966, 1969, 1973, 1977, 1978, 1983, 1987, 1993, 1998, 2001, 2009, 2010, 2016 and 2019.

Drought extends over the entire island of Guam.

Vulnerable assets are surface water sources that include the Fena Reservoir, rivers and springs. Agriculture that cannot be irrigated and trees depending on severity of the drought. Grass-fire risk is greatly increased.

Vulnerable jurisdictions include southern half of Guam and areas around Mount Santa Rosa.

Global climate change affects a variety of factors associated with drought on Guam. There is a high confidence that increased temperatures will lead to more precipitation falling as rain and increased evaporation and transpiration.

Probability of Future Events

Scientific studies of Guam's climate have shown that droughts on Guam typically follow a moderate or strong El Niño event. Generally, the intensity of a drought that occurs in the year after an El Niño event in the western North Pacific Ocean is proportional to the strength of the El Niño event. Weak El Niño events tend to occur every 3-5 years; moderate events every 7-10 years; and strong events every 20-30 years.

5.3.4 Earthquake

Nature

An earthquake is a sudden motion or trembling caused by a release of strain accumulated within or along the edge of the earth's tectonic plates. The effects of an earthquake can be felt far beyond the site of its occurrence. Earthquakes usually occur without warning and, after just a few seconds, can cause massive damage and extensive casualties. The most common effect of earthquakes is ground motion, or the vibration or shaking of the ground during an earthquake.

Ground motion generally increases with the amount of energy released and decreases with distance from the fault or epicenter of the earthquake. It causes waves in the earth's interior, also known as seismic waves, and along the earth's surface, known as surface waves. Two kinds of seismic waves occur: P (primary) waves are longitudinal or compressional waves similar in character to sound waves that cause back-and-forth oscillation along the direction of travel (vertical motion), and S (secondary) waves, also known as shear waves, are slower than P waves and cause structures to vibrate from side to side (horizontal motion). Also two kinds of surface waves occur: Raleigh waves and Love waves. These waves travel more slowly and typically are significantly less damaging than seismic waves.

In addition to ground motion, several secondary natural hazards can occur from earthquakes. Surface fault rupture, liquefaction, and lateral spread are addressed within this section. Landslide is addressed in **Section 5.3.12** (Slope Failure) and tsunamis are addressed in **Section 5.3.16** (Tsunami Inundation).

- **Surface Fault Rupture** is the differential movement of two sides of a fault at the earth's surface. Displacement along faults, both in terms of length and width, varies but can be significant (e.g., up to 20 feet in width and 200 miles in length). Surface faulting can cause severe damage to linear structures, including railways, highways, pipelines, and tunnels.
- **Liquefaction** occurs when seismic waves pass through saturated granular soil, distorting its granular structure, and causing some of the empty spaces between granules to collapse. Poor water pressure may also increase sufficiently to cause the soil to behave like a fluid for a brief period and cause deformations. Liquefaction causes lateral spreads (horizontal movements of commonly 10 to 15 feet, but up to 100 feet), flow failures (massive flows of soil, typically hundreds of feet, but up to 12 miles), and loss of bearing strength (soil deformations causing structures to settle or tip). Liquefaction can cause severe damage to property.
- **Lateral Spreads** are a type of landslide, but are distinctive because they usually occur on very gentle slopes or flat terrain and occur in a rapid fluid-like flow movement, caused by liquefaction. Ground failure is usually triggered by rapid ground motion, such as that experienced during an earthquake, but can also be artificially induced. When coherent material, either bedrock or soil, rests on materials that liquefy, the upper units may undergo fracturing and extension and may then subside, translate, rotate, disintegrate, or liquefy and flow. Lateral spreads are almost always discussed in conjunction with liquefaction.
- **Landslides** occur as a result of horizontal seismic inertia forces induced in the slopes by the ground shaking. The most common earthquake-induced landslides include shallow, disrupted landslides such as rock falls, rockslides, and soil slides. Debris flows are created when surface soil on steep slopes becomes totally saturated with water. Once the soil liquefies, it loses the ability to hold together and can flow downhill at very high speeds, taking vegetation and/or structures with it. Slide risks increase after an earthquake during the wet season. Landslides are further addressed in **Section 5.3.12** (Slope Failure).
- **Tsunamis:** As an Oceanic Plate subducts beneath a Continental Plate, it sometimes brings down the lip of the Continental Plate with it. Eventually, too much stress is put on the lip and it snaps back, sending shockwaves through the earth's crust, causing a tremor under the sea, known as an undersea earthquake. Factors that affect tsunami generation from an earthquake event include magnitude (generally, a 7.5 magnitude [M] and above), depth of event (a shallow marine event that displaces the seafloor), and type of earthquake (thrust as opposed to strike-slip). Tsunamis are further addressed in **Section 5.3.16** (Tsunami Inundation).

The severity of an earthquake can be expressed in terms of intensity and magnitude. Intensity is based on the damage and observed effects on people and the natural and built environment. It varies from place to place depending on the location with respect to the earthquake epicenter, which is the point on the Earth's surface that is directly above where the earthquake occurred. The severity of intensity generally increases with the amount of energy released and decreases with distance from the fault or epicenter of the earthquake. The scale most often used in the U.S. to measure intensity is the Modified Mercalli (MM) Intensity Scale. As shown in **Table 5-5**, the MM Intensity Scale consists of 12 increasing levels of intensity that range from imperceptible to catastrophic destruction. Peak ground acceleration (PGA) is also used to measure earthquake intensity by quantifying how hard the earth shakes in a given location. PGA can be measured in *g*, which is vertical acceleration due to gravity.

Magnitude is the measure of the earthquake strength. It is related to the amount of seismic energy released at the earthquake's hypocenter, the actual location of the energy released inside the earth. It is based on the amplitude of the earthquake waves recorded on instruments, known as the Richter magnitude test scales, which have a common calibration.

Table 5-5 Magnitude/Intensity/Ground-Shaking Comparisons

<table>
<tr><th>Magnitude</th><th>Intensity</th><th>PGA (% g)</th><th>Perceived Shaking</th></tr>
<tr><td rowspan="2">0 – 4.3</td><td>I</td><td><0.17</td><td>Not Felt</td></tr>
<tr><td>II-III</td><td>0.17 – 1.4</td><td>Weak</td></tr>
<tr><td rowspan="2">4.3 – 4.8</td><td>IV</td><td>1.4 – 3.9</td><td>Light</td></tr>
<tr><td>V</td><td>3.9 – 9.2</td><td>Moderate</td></tr>
<tr><td rowspan="2">4.8 – 6.2</td><td>VI</td><td>9.2 – 18</td><td>Strong</td></tr>
<tr><td>VII</td><td>18 – 34</td><td>Very Strong</td></tr>
<tr><td rowspan="3">6.2 – 7.3</td><td>VIII</td><td>34 – 65</td><td>Severe</td></tr>
<tr><td>IX</td><td>65 – 124</td><td>Violent</td></tr>
<tr><td>X</td><td rowspan="3">124 +</td><td rowspan="3">Extreme</td></tr>
<tr><td rowspan="2">7.3 – 8.9</td><td>XI</td></tr>
<tr><td>XII</td></tr>
</table>

Source: USGS 2011.

Location

The entire island of Guam is susceptible to the impact of an earthquake. This susceptibility reflects the presence of various known surface faults (**Figure D-13**) and past seismic activity felt on Guam (**Figures D-15 and D-16**).

Surface Fault Rupture: The general locations of known surface faults on Guam are shown on **Figure D-13**. **Figures D-15 and D-16** incorporate the reconnaissance mapping that included a preliminary assessment of potential seismic activity, but was not field-checked. Both sets of fault traces are shown on **Figure D-13**. To account for the uncertainty in the location of surface fault traces and the width of the deformation zone, the zones that are considered to have a potentially high surface faulting hazard encompass a 0.18-mile radial buffer (984.25 feet.) surrounding the faults. As shown on **Figure D-13**, many locations throughout Guam have surface fault traces. Approximately, 45.78 square miles of land area, or 21.8 percent of the island, are within the surface fault hazard zones, meaning that they have a higher threat of surface faulting from a known surface fault than areas farther away from the faults. The known surface faults are organized into concentrated areas on Guam. A large concentration of faults exists in the southwestern portion of the island, east of Apra Harbor, and in the northeast part of the island.

Liquefaction and Lateral Spreads: Previous studies have recommended rankings of high, moderate, and low, for the various areas of Guam that are potentially susceptible to liquefaction. This ranking is based on geological units and historical observations of each area. High potential areas contain beach sands, eolian sand, marine deposits, sands, and artificial fill. Areas with a moderate potential for liquefaction contain alluvial deposits in valleys. Low potential areas contain lagoon and estuarine deposits. **Figure D-14** shows the areas on Guam with high, moderate, and low potential for liquefaction to occur and the areas where liquefaction has occurred historically. Since lateral spreads are a result of liquefaction it is assumed that areas susceptible to lateral spreading correlate with the areas of liquefaction susceptibility.

Based on an analysis of the available geologic data, 2.98 square miles of Guam have a potential risk for liquefaction or lateral spreading to occur. Areas with a high risk for liquefaction or lateral spreading (also shown in **Table 5-17**) are mainly surrounding Tumon Bay and Apra Harbor, as much of the area surrounding Apra Harbor contains extensive areas of fill. This area has exhibited liquefaction and lateral spreading in historical earthquakes. In addition, the larger river valleys and along the coastlines of Merizo, Inarajan, and Agat are also susceptible to liquefaction and lateral spread.

The rest of Guam generally has a very low potential for liquefaction or lateral spreading to occur because the types of shallow material mapped at the surface are not conducive to liquefying. However, this assessment is limited by the scale and resolution of previous mapping on Guam; small areas of sediments more susceptible to liquefaction may exist in these very low potential areas.

Previous Occurrences

The most significant recent earthquake on Guam occurred on August 8, 1993. This M 7.8 event occurred 31 miles south of Guam at a depth of 37 miles along the Mariana Trench. No consensus exists as to the source of this earthquake, but evidence from a recent study of aftershocks suggests that this earthquake was an interplate event (i.e., it occurred between the Pacific plate and the Philippine Sea plate). Liquefaction and lateral spreading caused major damage to commercial and naval port facilities. Landslides were predominantly small local slumps and rockfalls along limestone bluffs. Buildings were damaged or destroyed throughout the island. The preliminary estimate of damage to commercial buildings was $112 million. No compiled damage cost is available for this earthquake.

One Presidentially declared earthquake disaster has occurred on Guam. On October 12, 2001, a M 7.3, maximum MM Intensity VII earthquake struck Guam. This seismic event was believed to have caused one injury, but no published estimates of total damage are available. According to the information available, the center of the earthquake was southeast of the initial centerpoint of the August 1993 series, and the earthquake had the following effects: the power was lost, a new school in Piti was affected, several schools in the Santa Rita area were affected, many buildings were damaged, and utilities were disrupted. No other earthquakes associated with damage have been reported. Information on other significant earthquakes since 1975 is provided in **Table 5-6**.

Table 5-6 Recent M 5.7 or Greater Earthquakes Felt on Guam, 1975–2019

Event Date	Description	Magnitude	MM Intensity
1 Nov 1975	From the same area as the 1936 event. Damage in excess of $1,000,000. No landslides were noted. This quake was 70 miles deep and was preceded by loud subterranean noises. Many businesses lost stock from shelves, and a number of structures were damaged; only one injury was reported. The earthquake was felt strongly in many parts of the island. Epicenter 12.5 miles north of the island	7.1	VIII
13 Feb 1983	One person slightly injured at Tamuning/Tumon/Tumon. Felt throughout Guam. Epicenter about 25 miles north of the island. Minor damage reported in northern Guam.	6.3	V
5 Apr 1990	Felt on Guam. Also felt on Saipan.	7.3	IV
8 Aug 1993	The most severe examples of ground failure were at the filled area of Cabras (Piti power plant and commercial port) and at the Navy wharfs across the harbor. Two cases of building failure in the Tumon area were noted. Old residential units in the Apra Heights housing area suffered notable damage and were also razed. No bridge failures occurred but the Talofofo, Ylig, and Pago bridges required repairs as well as the utilities along the bridges. Forty-eight people injured on Guam. Extensive damage (IX) to hotels in the Tumon Bay area. Damage (VII) occurred at several locations in the northern half of the island. One end of the approach to a bridge at Pago Bay fell more than 18 inches. Many landslides and rockslides were reported, mainly in the southern half of the island. The preliminary estimate of loss from damage to commercial buildings is placed at $112 million and loss from damage to private residences is estimated at several million dollars.	7.8	IX
23 Apr 1997	Two separate earthquakes occurred from the fault plane of the August 1993 series. Four people injured and some damage to buildings on Guam. Felt (VII) at Inarajan, Merizo, and Yona; (VI) in central Guam; (IV) at Dededo and Yigo. A M 5.7 earthquake was followed 5 seconds later by a M 6.3 earthquake (not an aftershock). Centered about 27 miles west of Rota. Originated at a depth of 65 miles.	5.7; 6.3	VII
12 Oct 2001	Southeast of the initial shock of the August 1993 series. Power was lost. The new school in Piti (on alluvial clay) was most conspicuously affected as well as schools in the Santa Rita area. One person injured, many buildings damaged (VII) and utilities disrupted on Guam.	7.3	VII
26 Apr 2002	Northwest of the August 1993 initial shock. Power was lost through most of Guam. At least 5 people slightly injured and some minor damage (VII) to buildings on Guam. Water and sewer lines broke and power outages occurred throughout the island.	7.1	VII
9 May 2008	Felt on Guam, also felt on Saipan. No reports of damage or injury.	6.7	IV
11 Sept 2012	155 miles southwest of Hagatna with an epicenter depth of more than 6 miles. Felt on Guam. No reports of damage or injury.	5.8	V
17 Sep 2014	26.7 miles northwest of Piti Village, Guam. No reports of damage or injury.	6.7	V

Sources: GHS/OCD 2019; USGS NEIC 2019; EERI 1995; WERI 1998; Repetti 1948.

Surface Fault Rupture: Although surface fault ruptures have not been observed historically along any of the known faults on Guam (**Figure D-13**), abundant geologic evidence shows that many faults ruptured prehistorically in the late Quaternary (past 130,000 years) and, thus, have the potential for surface rupture. This geologic evidence of prehistoric ruptures includes fault scarps offsetting limestones that are likely Quaternary or even late Quaternary in age, offsets of late Quaternary marine terraces, and even offsets of young algal pools.

Liquefaction and Lateral Spreads: The only readily available information on historical liquefaction and lateral spread events concerns the earthquake that occurred on August 8, 1993. The areas of historic liquefaction and lateral spread are shown on **Figure D-14**. The occurrences were originally documented in the 1995 EERI report on this event. As shown on **Figure D-14**, liquefaction and lateral spreading was observed at the following locations:

- In the areas surrounding Apra Harbor and Piti Power Plant, liquefaction occurred where coral fill material overlies fine-grained lagoonal and estuarine deposits. The groundwater in these areas was approximately 7 to 8 feet below ground surface. At the commercial port facility, liquefaction and lateral spreading caused horizontal displacement of up to 24 inches and crane tracks and bulkheads were warped. Cracks were observed that extended for 200 to 300 feet and were up to 8 feet deep. According to information on the website of the Guam Power Authority, damage of $8-$10 million occurred at the port
- At the Naval Station port facilities, most of the wharves sustained structural damage from liquefaction and lateral spreading. The Navy allocated $2.8 million toward initial wharf repairs, but the estimate for the total cost of the damage was $25.15 million.
- Extensive evidence of liquefaction was observed at the Piti Power Plant. Ground fissures and sand boils ejected coral sands. Liquefaction caused up to 4 feet of settlement. Although liquefaction and lateral spreading caused nonstructural damage, no structural damage occurred to the plant due to liquefaction or lateral spreading.
- Liquefaction was evident near the new courthouse in downtown Hagatna. This area was developed with fill material on top of fine-grained Hagatna marsh sediments. No cost estimate of the damage to this area is available.

Probability of Future Events

Fault and seismic data for the region in which Guam is located are generally scarce. Guam is in a remote region of the Pacific Ocean, and the historical seismic catalog for moderate-sized events is most likely incomplete and the historical record for large events is likely inadequate because the recurrence intervals for subduction zone earthquakes may be long. However, based on recorded occurrences from 1975-2013, an earthquake of significant size (>M 5.7) is likely to be felt on Guam every 4-5 years.

The 1999 Global Seismic Hazard Assessment Program (GSHAP) conducted a generalized global probabilistic seismic hazard analysis that included Guam. GSHAP calculated PGAs with a 10 percent chance of being exceeded in 50 years. Guam lies in the PGA contour range of 0.16g to 0.24g. The GSHAP analysis only considered regional source zones; the potential hazard from the subduction zone or crustal faults was not included in the analysis.

Surface Fault Rupture: Beyond identifying the general locations of the potentially active fault traces on Guam, the data available on these faults are not adequate to characterize the faults and analyze the probability for surface faulting to occur. To fully characterize the hazards from surface faulting, the exact locations, ages, sense of motion, and dips associated with the faults need to be researched and identified. However, the approximate locations of many potentially active faults have been identified, and these faults do show evidence of movement that is likely Quaternary or even late Quaternary.

Liquefaction and Lateral Spreads: Specific data, including depth to water table, boring logs, blow count information, and detailed age data for the geological units, none of which are available for Guam, are generally used to determine the probability for liquefaction and lateral spreading to occur. However, as described above, based on recorded occurrences from 1975-2013, an earthquake is likely to be felt on Guam every 4-5 years. Liquefaction and lateral spreading on Guam may occur as a result of these earthquake events.

5.3.5 Flooding

Nature

Flooding is one of the most common natural hazards; it occurs whenever rainfall accumulates in an area faster than it can drain off or can be absorbed by the soil. This accumulation causes an overflow from a water body onto an adjacent floodplain. However, all floods are not alike, and different areas are susceptible to different types of flooding. Guam is vulnerable to coastal flooding, riverine flooding and stormwater runoff, and flash flooding. Flooding on Guam is often associated with tropical cyclones; this connection is described below, but for further information specific to tropical cyclones, see **Section 5.3.15** (Tropical Cyclone). Severe flooding can also occur without a tropical cyclone.

Flooding is a major concern for the Government of Guam. Several initiatives starting as far back as 1975 were done to study the flooding problems on Guam. Various agencies such as the Bureau of Statistics and Plans, Guam Coastal Management Program, US Army Corps of Engineers, Federal Highways Administration, Department of Public Works, Office of Civil Defense and the University of Guam contribute to work over the past 40 years. The Guam Coastal Management Program and the US Army Corps of Engineers is currently updating the 1980 Guam Comprehensive Flood Study.

Coastal Flooding: Coastal flooding in the western North Pacific Ocean is primarily due to inundation from ocean water that is associated with storm surges and wind-driven waves. A storm surge occurs in the right-front quadrant of the storm with respect to its direction of motion where the seawater surface of an approaching tropical cyclone is elevated in the shape of a mound. This occurs because of the extreme low pressure that exists within and near to the eye of a tropical cyclone and the piling up of water in the right-front quadrant of the storm with respect to its direction of motion. The sea level can be as much as 5 feet higher than normal during a storm surge in a strong typhoon due to the low pressure and much higher due to the piled-up water. The strong winds associated with a tropical cyclone also produce wind-driven waves that ride on top of the storm surge mound. With the addition of an astronomical high tide, incursion of seawater onto a normally dry land area (i.e., coastal flooding and inundation) can occur.

When a tropical cyclone passes directly over a small island, all shorelines of the island can be exposed to coastal flooding. Bays, river outlets, and reefs that occur on or close to a coast can exacerbate coastal flooding. The small size and restricted entrances of some bays can act to focus and contain the high water associated with storm surges and wind-driven waves. Strong winds often drive this high water toward the shore; the result can be a coastal flooding event. Raised sea levels can prevent rivers and streams from draining into the ocean and can cause the water in the rivers and streams to back up. This backup of water can result in flooding near the outlet of these waterways.

Generally, healthy reefs have a damping effect on storm surges and wind-driven waves. The shallower the water over a reef and the wider the reef, the more damping the effects of the reef on a storm surge and wind-driven waves. Conversely, the deeper the water over the reef and the narrower the reef, the more coastal inundation and coastal flooding that can occur. Coastal flooding and inundation are greatest when wind-driven waves riding on top of a storm surge approach a reef in a perpendicular direction. The force of the incoming storm surge can reduce the normal drainage of water across a reef and cause water to build up on the inside of a reef. This water buildup can lead to increased coastal flooding. A channel in a reef or a location where a reef folds into a coastline can serve as funnel for large amounts of water to come onto the shore in the form of large waves. This phenomenon can also result in increased levels of coastal flooding.

Storm surges can also result in coastal flooding in urban areas by causing storm drains to back up in low-lying areas. When a storm surge elevates the sea water to the same elevation as or above the elevation of storm drain outlets that drain into the ocean, the storm drains are not able to drain, and the storm runoff backs up into the storm drains and onto the nearby streets.

Riverine Flooding and Stormwater Runoff: The most common type of flooding is riverine flooding, also known as overbank flooding. Riverine floodplains range from narrow, confined channels in the steep valleys of mountainous and hilly regions to wide, flat areas in plains and coastal regions. The amount of water in the floodplain is a function of the size, land cover, and topography of the contributing watershed, the regional and local climate, and the land use characteristics of the floodplain. In steep valleys, flooding is usually rapid and deep, but of short duration. In flat areas flooding is typically slow, relatively shallow, but can last for longer periods of time.

On Guam, flooding in rivers and streams is typically caused by prolonged periods of rainfall from tropical cyclones, monsoon surges, or slow-moving thunderstorms. These systems can saturate the ground and overload the rivers in numerous smaller basins that drain into larger rivers. Intense rates of rainfall (greater than 1 inch per hour) can lead to flash flooding. Flash flooding is most likely to occur in valleys in mountainous areas. The northern ecoregion of Guam has essentially no stream drainages because the area consists primarily of permeable limestone, which results in rapid infiltration of water even during heavy rainfall. Little or no surface water runoff occurs in this area, except where there are impermeable surfaces such as streets and parking lots. However, the southern ecoregion of Guam has a dense network of rivers and streams. This area consists primarily of basaltic volcanic rocks, which have limited infiltration capacities.

Heavy rainfall and the associated flooding can cause large amounts of soil and debris to enter into rivers. Debris can also enter rivers if it has been blown there by severe winds (see **Section 5.3.11** [Severe Wind]). Debris that becomes a part of floodwaters can cause damage to the culverts and bridges that floodwaters are either flooding through or around. This type of debris can completely dam bridges, culverts, and other drainages and cause floodwaters to bypass these structures and enter into areas that typically do not receive floodwaters. The dammed drainages can suddenly give way and cause flash-flood conditions farther downstream. In addition, large amounts of soil and debris can become deposited on the reefs surrounding tropical islands. This deposition of silt and debris is highly detrimental to the health of the coral polyps that create and maintain the reefs.

Although heavy rainfall events associated with tropical cyclones, particularly typhoons, and monsoon surges are well documented and acknowledged as a major hazard, Guam also experiences heavy rainfall events that are not associated with tropical cyclones or monsoons. These events result in significant stormwater runoff that may overwhelm local stormwater systems and local river and stream systems, if any, and cause localized flooding. Although this type of flooding is recognized as a hazard, the areas subject to this type of subhazard have not been well documented to date and are not identified on FIRMs because these events are typically relatively small in size and extent.

Flooding due to stormwater runoff or street flooding often occurs when storm drains cannot convey the amount of water that could flow through them. This hazard can be due to high rates of rainfall, inadequate drainage design, storm surges, and/or debris blocking the storm drain conveyances. As the amount of paved surface increases in Guam due to the growth of urban areas, the amount of stormwater runoff will increase. This increase, when combined with inadequate stormwater runoff conveyances, can lead to increased flooding.

Seismic forces, lack of vegetation, and heavy rainfall generally propagate slope failure on Guam. Seismic forces tend to destabilize slopes and heavy rainfall can saturate the destabilized slopes and dislodge loose rocks. (A detailed discussion of slope failure is provided in **Section 5.3.12** [Slope Failure].) These events can result in rockslides, mudflows, and debris flows. These hazards can further exacerbate floods or result in the changing of floodplains.

Flash Flooding: A flash flood, also a fresh water source, is the fastest-moving type of flood; this hazard can fill a normally calm area with a rushing current in a relatively small amount of time. Flash floods in Guam are caused by heavy rain that is often, but not always, associated with a tropical cyclone. Flash floods occur when water falls too quickly on saturated soil or dry soil that has poor absorption ability. This water cannot be absorbed into the soil and therefore flows elsewhere.

The main defining characteristic of a flash flood is the timescale in which it develops; a flash flood generally develops in less than 6 hours. Flash flood waters also move at very fast speeds and have the power to move boulders, tear out trees, and destroy both buildings and transportation infrastructure. During a flash flood, walls of water can reach heights of 10 to 20 feet, scouring the walls of mountain streams. This combination of power and suddenness makes flash floods particularly dangerous.

Heavy persistent rainfall on Guam is more often associated with slow-moving tropical cyclones than with fast-moving storms of comparable intensity. Many of the rain events on Guam occur from storms that are of less-than-typhoon intensity. The heaviest rains in typhoons occur in a concentrated area near the eye. Therefore, a typhoon needs to pass relatively close to an area for the area to receive the heaviest rains of the typhoon. Weaker storms are less organized than a typhoon, but heavy rains can extend farther from the center and can therefore have a broader sweep of heavy squalls than a typhoon. Monsoon surges can continually feed moisture into a tropical cyclone or they can independently produce copious rains and flash floods on the island.

Rainfall is generally higher in mountainous areas than over flat terrain. For this reason, flash floods are generally constrained to the southern half of the island of Guam. Flash floods can occur when heavy rain (e.g., 2 inches per hour) falls for 1 hour or less or when heavy rain (e.g., 1 inch per hour) falls for more 2 or more hours in mountainous areas. Even rainfall of 1 inch per hour for 1 hour or heavier rates of rainfall for shorter periods can cause drainage systems to overflow and force manhole covers to pop up, a hazard to both vehicles and pedestrians.

Location

Coastal Flooding: As shown on **Figure D-17**, the entire coast of Guam is susceptible to coastal flooding. Apra Harbor is particularly susceptible.

Riverine Flooding and Stormwater Runoff: As shown on **Figure D-17**, riverine flooding generally occurs in the southern portion of Guam, near the villages of Agat, Santa Rita, Talofofo, Inarajan, Merizo, Umatac. Some central locations, such as Maina and Chalan Pago are also susceptible to riverine flooding. Although stormwater runoff is recognized as a hazard, the areas subject to this type of subhazard have not been well documented to date and are not identified on FIRMs because these events are typically relatively small in size and extent.

Flash Flooding: WERI has reported that flash floods occur in the mountainous areas of Guam, but no comprehensive data are available on the locations of past occurrences of flash flooding on Guam. However, return frequencies of various rainfall rates have been determined.

Previous Occurrences

Flooding on Guam occurs in a number of ways, and each may be affected by climate change. Surface water flooding occurs where heavy rainfall cannot absorb into the ground or drain away. River flooding, closely linked to surface flooding, occurs when streams burst their banks.

Coastal Flooding: Although previous occurrences of this hazard are not well documented, coastal flooding has been a significant and recurring hazard on Guam. The combination of heavy rains, storm surges, the presence of developed urban areas at low elevations along the coast, reef structure, and small bay entrances has produced frequent coastal flooding during tropical cyclones.

Table 5-7 shows the major typhoons passing near or over Guam from 1950 to 2013, with their modeled wave heights. The coastal inundation from Super Typhoon Yuri in November 1991, Typhoon Omar in August 1992, Typhoon Gay in November 1992, and Super Typhoon Pongsona in December 2002 has been well documented. Typhoon Omar and Typhoon Gay caused coastal inundation of 9 and 11 feet, respectively, above mean high tide in areas that were (and still are) developed at low elevations along the western coast. Super Typhoon Yuri caused near-historic inundation on Guam's eastern coast from Pago Bay at the northern end to the Saluglula Pools and the Tipoco Cemetery in Inarajan at the southern end. Super Typhoon Pongsona produced maximum coastal inundation of approximately 18 feet on coastal areas of eastern Guam. The coastal inundation associated with Typhoons Tingting and Chaba was estimated at 6 feet.

Coastal flooding has generally occurred in southern and eastern Guam along bays that have small restricted entrances that focus and contain the high water generated by the storm surge, wind-generated waves, and large upland discharges of heavy rains that result during tropical cyclones. Inarajan Bay, Talofofo Bay, Ylig Bay, and Pago Bay experience frequent coastal flooding along their adjacent uplands when tropical cyclones pass to the south of Guam. Seawater in Pago Bay is sometime driven over an elevated ridge of land to form an inland lake. During Super Typhoon Yuri, several houses floated off their foundations in this temporary coastal flood lake.

Table 5-7 Estimated Wave Heights of Major Tropical Storms and Typhoons, 1950–2019

Date	Name	Modeled Significant Wave Height (feet)
08/11/1951	Tropical Cyclone Marge	13.7
11/11/1962	Super Typhoon Karen	19.9
09/05/1964	Typhoon Sally	8
11/23/1968	Tropical Storm Ora	6.2
05/21/1976	Typhoon Pamela	22.6
11/08/1977	Typhoon Kim	12.5
08/17/1979	Tropical Depression Judy	3
10/03/1983	Tropical Storm Mac	12.6
11/12/1984	Typhoon Bill	17.4
11/27/1991	Super Typhoon Yuri	30
08/28/1992	Typhoon Omar	17.5
10/21/1992	Typhoon Brian	10.5
11/23/1992	Typhoon Gay	14.5
12/16/1997	Super Typhoon Paka	22.2
12/08/2002	Super Typhoon Pongsona	25
01/18/2003	Tropical Storm Yanyan	9
04/14/2003	Super Typhoon Kujira	8
09/05/2003	Super Typhoon Maemi	8
06/27/2004	Typhoon Tingting	15
08/22/2004	Typhoon Chaba	15
09/20//2004	Typhoon Meari	8
10/12/2004	Typhoon Tokage	8
10/20/2004	Typhoon Nock-Ten	9
12/19/2004	Tropical Storm Noru	8
01/16/2005	Tropical Depression Kulap	8
05/31/2005	Tropical Depression Nesat	8
08/25/2005	Tropical Depression Talim	8

Table 5-7 Estimated Wave Heights of Major Tropical Storms and Typhoons, 1950–2019

Date	Name	Modeled Significant Wave Height (feet)
08/31/2005	Super Typhoon Nabi	9
08/05/2006	Super Typhoon Saomi	9
04/02/2007	Typhoon Kong-Rey	9
12/11/2008	Typhoon Dolphin	10
10/15/2009	Super Typhoon Lupit	8
10/27/2009	Typhoon Mirinae	8
11/25/2009	Super Typhoon Nida	8
05/22/2012	Typhoon Sanvu	10
10/10/2013	Typhoon Wipha	8
10/16/2013	Super Typhoon Francisco	12
04/27/2014	Typhoon Tapah	8
07/03/2014	Super Typhoon Neoguri	8
07/12/2014	Super Typhoon Rammasun	12
07/30/2014	Super Typhoon Halong	12
10/05/2014	Super Typhoon Vongfong	15
03/15/2015	Tropical Storm Bavi	11
05/15/2015	Super Typhoon Dolphin	24
07/05/2015	Typhoon Chan-hom	12
08/02/2015	Super Typhoon Soudelor	10
08/15/2015	Typhoon Goni	13
10/16/2015	Typhoon Champi	12
11/20/2015	Typhoon In-Fa	20
08/23/2016	Tropical Storm Fourteen	8
09/09/2017	Typhoon Talim	8
10/24/2017	Typhoon Saola	8
07/04/2018	Super Typhoon Maria	13
08/15/2018	Typhoon Soulik	8

Table 5-7 Estimated Wave Heights of Major Tropical Storms and Typhoons, 1950–2019

Date	Name	Modeled Significant Wave Height (feet)
09/10/2018	Super Typhoon Mangkhut	18
09/20/2018	Super Typhoon Trami	8
09/29/2018	Super Typhoon Kong-Rey	8
10/25/2018	Super Typhoon Yutu	27
02/23/2019	Super Typhoon Wutip	25

Sources: WERI 1999, NCDC 2014, NWS-WFO Guam 2019.

Riverine Flooding and Stormwater Runoff: The flood events on Guam reported in the National Climatic Data Center's (NCDC's) Storm Event Database are attributed to localized heavy rainfall events from monsoon surges, tropical cyclones, or a combination of the two. In addition to coastal flooding (addressed in the preceding section), flooding on the island also occurs in riverine areas and urban areas.

In 1975 and 1976, several flood hazard studies were completed to provide site-specific flood information at the following locations:

- Agana River
- Agat Area
- Asan Area
- Geus River
- Inarajan River
- Asso River
- Pago River
- Salinas River
- Tamuning Area
- Umatac River
- Ylig River

Individual flood hazard studies were prepared to provide information on flood potential and flood hazards at various locations. Each report includes a history of past floods in the area and identifies areas that are subject to flooding in the future. It does not include solutions to address flood problems, however.

The 1980 Guam Comprehensive Study resulted in two documents: 1) Flooding and Drainage on Guam, a reference handbook of basic information regarding Guam's precipitation, streamflow and related hydrologic data, and 2) the Guam Storm Drainage Manual, a design manual of policies, standards, and design criteria for storm drainage facilities.

In 1982, USACE completed the report Alternative Solutions for Flood Prone Areas in Guam to provide the Government of Guam with comprehensive alternative plans for those areas planned for development. This study establishes design criteria for drainage areas, specifies capacity, types and locations for drainage facilities, includes preliminary cost estimates, and suggests legislation for floodplain regulation. Individual areas studied include Agat, Umatac, Merizo, Inarajan, and Agana.

In 1983, USACE completed another report with the same title, Alternative Solutions for Flood Prone Areas in Guam, to aid the Government of Guam in resolving the flood and drainage problems in Santa Rita, Yigo, and Dededo.

In June 2003, the Water and Environmental Research Institute of the Western Pacific (WERI) at the University of Guam published Technical Report No. 102, Creation of a 50-Year Rainfall Database, Annual Rainfall Climatology, and Annual Rainfall Distribution Map for Guam. The report includes an annual rainfall distribution map for Guam (see Figure 1-1) that visually identifies the rainfall maxima and minima on the island. It also concludes that, unlike the Hawaiian Islands, the topography of Guam has little effect on rainfall during major precipitation events (such as during a typhoon).

Preliminary regional flood frequency regression equations were developed in 2010 by USACE to estimate peak flow for a particular frequency event at ungagged sites in southern Guam. These equations were derived from 14 USGS stream gages with 10 or more years of record and are applicable for southern Guam watersheds with drainage areas between 0.28 square miles (mi2) and 7.13 mi2. Flood frequency analysis of data at each stream gage was run using Bulletin 17B procedures with a generalized skew of 0.50 having a mean square error of 0.174. The equations developed are below:

Q2 = 729 (DA0.843)

Q5 = 1,160 (DA0.846)

Q10 = 1,360 (DA0.849)

Q20 = 1,700 (DA0.854)

Q50 = 2,210 (DA0.860)

Q100 = 2,640 (DA0.864)

Q200 = 3,770 (DA0.870)

Q500 = 3,860 (DA0.877)

Where Qx = recurrence interval in years and

DA = drainage area in square miles

A GIS-Based Watershed Management Plan for the Piti-Asan Watersheds, published in October 2012 through WERI as Technical Report No. 139, evaluates existing and future conditions of the Piti and Asan watersheds and recommends various management strategies to address soil erosion issues. These challenges and recommendations were important to keep in mind during development of our own recommendations to address the issue of riverine flooding.

Predictions of Flow Duration Curves at Ungaged Sites in Guam, published in January 2015 through WERI as Technical Report No. 154, estimates the average flow for gaged and ungaged sites in Guam. This data can be used to represent the baseflow in the hydraulic model.

Typhoon Chata'an was recorded to have delivered rainfall totals that exceeded 21 inches over the mountainous areas of southern and central Guam. Flooding and siltation occurred in Fena Reservoir during this event; as a result, there was a lack of potable water for several days. This storm also caused flooding in southern Guam that resulted in numerous landslides and severe erosion along watercourses. All the stream-gauging stations operated by the U.S. Geological Survey (USGS) were damaged or destroyed during these floods. Peak flows in many rivers in southern Guam reached record levels during this storm. Four of the nine gauging sites had water elevation recurrence intervals that were determined to be greater than the 100-year flood level. A river gauge on the Ylig River recorded a peak height of 23.45 feet, which was 4.82 feet higher than the previous maximum level recorded in 1953. The Fena Reservoir level was 5.36 feet above the spillway crest and 0.86 feet higher than the previous maximum recorded level in 1953. The northern part of Guam received less than 10 inches of rain, and the central part of the island received 10 to13 inches. Recorded rainfall totals were determined to be less than what was actually received because severe winds caused water to be sucked out of gauges or the gauges did not catch the rain well when the rainfall was occurring along a horizontal plane due to severe winds.

Few direct historical accounts of flooding on Guam exist for events before 2002, so the most useful historical information about floods on Guam can be obtained by examining historical rainfall events. Large rainfall events on Guam are generally attributed to tropical cyclones that move slowly across the island. In 1976, Typhoon Pamela dropped over 27 inches of rain in 24 hours as it moved across the island at 7 mph. Over half of the heaviest rain events on Guam occur from weak tropical cyclones or monsoon surges. The highest recorded hourly rain rate was from Super Typhoon Pongsona, which delivered 7.22 inches per hour in the eye wall cloud.. It is believed that many of the intense typhoons and super typhoons that have crossed Guam, such as Typhoon Pamela and Super Typhoon Karen, have delivered large quantities of rain that were under-recorded due to rain gauge destruction, malfunction, or power outage. Most recently, Typhoon Tingting delivered a recorded 16 inches in a 24-hour period on June 27, 2004. Typhoon Chaba produced heavy rains with a peak 24-hour total of 9.05 inches.

The one recorded event of flooding from stormwater runoff on Guam occurred in August 1984; the flooding occurred after a rainfall of 15.18 inches was recorded. The Governor of Guam issued an emergency declaration that noted that flooding in the Fineli Beach Area of Agat occurred as a result of stormwater runoff from higher areas. This is a common occurrence when the coastal waters are elevated and rainfall cannot run back in to the open ocean.

Many urban storm drains are overwhelmed if rainfall exceeds a rate of 1 inch per hour. Such rainfall rates can occur on Guam during strong monsoon surges and tropical cyclones. Rainfall rates during typhoons and super typhoons often exceed 4 to 5 inches of rainfall per hour at their peak of rainfall intensity. Poor storm drain conveyance in conjunction with storm surges can exacerbate coastal flooding. No street flooding data are readily available for Guam. In built-up areas generally subjected to coastal flooding, street flooding and coastal flooding are generally inseparable events.

Flash Flooding: Flash floods in Guam are poorly documented; no comprehensive record of these events in Guam is available. However, a few occurrences of flash flooding have been noted. In 1999, the Red Cross responded to a flash flood, providing assistance to 14 families. The most significant flash flooding event occurred in June 2004, during Typhoon Tinting. Typhoon Tinting was still a tropical storm when it passed over Guam, but it brought record-breaking rainfall to Guam. In 24 hours, 21.85 inches of rain fell on Guam; this rainfall shattered both the record for highest single-day rainfall on Guam and the record for the highest monthly rainfall for June. Although over 20 inches of rain fell in 24 hours over much of Guam during this event, rainfall was somewhat less over the northeastern portion of Guam where 11.33 inches fell at Andersen Air Force Base in 30 hours. These extreme levels of rainfall caused island-wide flash floods and mudslides, road closures, and inundations.

Although the flash flooding event in 2004 caused much damage for Guam, this type of event is not common. WERI has reported that flash floods generally occur in the mountainous areas of Guam and do not result in significant damage.

The distribution of rainfall on Guam is mixed; the events that produce more than 10 inches of rain per day come from near-direct or direct passages of tropical cyclones. According to a 2004 WERI report, the maximum rainfall rate observed in the eye-wall cloud of typhoons affecting Guam was measured in Typhoon Pongsona (2002) at about 0.12 inches/minute over 60 minutes or about 7.22 inches per hour. However, rainfall rates could be somewhat higher during stronger typhoons or during comparable typhoons passing over the more mountainous terrain of central Guam. This likelihood is reflected in the increasing rates with respect to return periods (**Tables 5-8 and 5-9**). For events producing less than 10 inches per day, the source may be peripheral thunderstorms of more distant tropical cyclones, island-induced thunderstorms, or thunderstorms advected into Guam. These events are most commonly associated with upper cold low-pressure systems embedded in the Tropical Upper Tropospheric Trough (a common feature of the summer troposphere in the western North Pacific Ocean). These events are more short-lived than typhoon events, but can have higher, short-term intensities.

Table 5-8 Rainfall for Typhoon Eye-Wall (inches)

Return Period	1-minute	5-minute	10-minute	15-minute
2-year	0.09	0.45	0.90	1.35
5-year	0.10	0.50	1.50	1.50
10-year	0.11	0.55	1.10	1.65
15-year	0.12	0.60	1.20	1.80
25-year	0.13	0.65	1.30	1.95
50-year	0.14	0.70	1.40	2.10
100-year	0.16	0.80	1.60	2.40

Rainfall amounts in inches for Typhoon Eye-Wall occurrences for the designated time periods and the designated return periods.

Table 5-8 Rainfall for Typhoon Eye-Wall (inches)

Return Period	1-minute	5-minute	10-minute	15-minute

Table 5-9 Rainfall for Non-Tropical Cyclone Thunderstorms (inches)*

Return Period	1-minute	5-minute	10-minute	15-minute
2-year	0.10	0.50	0.89	1.25
5-year	0.12	0.60	1.07	1.50
10-year	0.14	0.70	1.24	1.74
15-year	0.15	0.75	1.33	1.86
25-year	0.16	0.80	1.42	1.99
50-year	0.18	0.90	1.60	2.24
100-year	0.20	1.00	1.78	2.49

Rainfall amounts in inches for Non-Tropical Cyclone Thunderstorms for the designated time periods and the designated return periods.

*Table 5-9 slightly modified based on a personal communication with Dr. Bill Merkel and Dr. Merkel's draft Rainfall-Frequency tables for Guam and the CNMI.

Probability of Future Events

Coastal Flooding: Coastal flooding on Guam is mainly caused by storm surges associated with tropical storms. On average, three tropical storms and one typhoon pass within 180 nautical miles of Guam each year.

Riverine Flooding and Stormwater Runoff: On Guam, riverine flooding is typically caused by prolonged periods of rainfall from slow-moving tropical cyclones or monsoon surges during the wet season (June – December). As noted above, on average, three tropical storms and one typhoon pass within 180 nautical miles of Guam each year.

No methodology has been employed to quantitatively determine the frequency of flooding on Guam due to stormwater runoff. To a certain extent, the probability for flooding due to stormwater runoff can be based on the designed conveyance capacity of a stormwater facility and the ability of the system to prevent the settling of sediments at drains.

Guam is updating its Comprehensive Flood Mitigation study and anticipates high probability of flooding impacts in the future. Hagatna River, Manell watershed, upper Namo River (Santa Rita), and Umatac River remain a high priority flood mitigation area of Guam.

Flash Flooding: High levels of rainfall are common on Guam, but flash floods require high levels of rainfall in very short periods. Flash flooding is most likely to occur during the wet season (June – December), when westerly moving storm systems bring heavy showers or steady and sometimes torrential rain.

5.3.6 Hazardous Materials

Nature

Hazardous materials (HAZMAT) includes hundreds of substances that pose a significant risk to humans. These substances can be highly toxic, reactive, corrosive, flammable, radioactive, or infectious. Because of the nearly ubiquitous presence of HAZMAT, hundreds of hazardous material release events occur annually in the United States that contaminate air, soil, or groundwater resources, potentially triggering millions of dollars in cleanup costs, human and wildlife injuries, and occasionally human deaths.

Hazardous material releases may occur from any of the following:

- Fixed site facilities (e.g., refineries, chemical plants, storage facilities, landfills, hardfills, manufacturing facilities, warehouses, wastewater treatment plants, swimming pools, dry cleaners, automotive sales/repair, and gas stations)
- Highway transportation (e.g., tanker trucks, chemical trucks, or highway tankers)
- Marine transportation (e.g., bulk liquefied gas carriers, oil tankers, or tank barges)
- Air transportation (e.g., cargo packages)
- Pipelines (pipelines transporting liquid petroleum, natural gas, or other chemicals)

HAZMAT can be released accidentally by a human-caused action, such as an unintended release from a pressure valve or an oil tanker accident, or due to a natural hazard event. In addition, natural hazards can complicate response activities. The impact of earthquakes or severe winds on fixed facilities can be particularly bad due to the impairment of the physical integrity or even failure of containment facilities. The threat of a HAZMAT event can be magnified by a natural hazard due to restricted access for response personnel to an area with a HAZMAT release, reduced fire suppression and spill containment capability, and even complete cut-off of response personnel and equipment. The risk of terrorism involving HAZMAT is considered a major threat due to the location of HAZMAT facilities and transport routes in populated areas and the limited anti-terrorism security at these facilities.

Of the hundreds of HAZMATs that are used, the HAZMATs that pose the greatest risk for causing catastrophic emergencies are identified as Extremely Hazardous Substances. These chemicals are identified by the U.S. Environmental Protection Agency in *List of Lists: Consolidated List of Chemicals Subject to the Emergency Planning and Community Right-To-Know Act (EPCRA) and Section 112 of the Clean Air Act* (EPA 2001).

Location

The following major HAZMAT facilities have been identified for this plan:

- **Sewage treatment plants**: As shown on **Figure D-18**, 3 sewage treatment plants with ocean outfall facilities are located on Guam. (Formerly, there were four sewage treatment plants with ocean outfall facilities; one plant located at the commercial port has been placed out of operation since the 2008 Guam HMP was completed.) The outfall facilities generally consist of a pipe placed on the sea floor that extends a certain distance from the shoreline and ends with a diffuser piece that releases the sewage. The contamination medium during a sewage hazard event will be coastal surface water. A sewage hazard event will occur if a sewage outfall pipe is damaged close to shore and sewage is released closer to shore than intended. The total coastal surface water potentially affected by a sewage hazard event within a 1-mile radius of each of the 3 sewage plants is 6.2 square miles. This hazard is expected to affect only coastal surface water, and not any of Guam's land area.
- **National Pollutant Discharge Elimination System air and water permitted facilities**: As shown on **Figure D-19**, 22 facilities on Guam have National Pollutant Discharge Elimination

System (NPDES) permits to discharge certain quantities of hazardous waste into surface waters. An additional 15 facilities also have the potential to discharge HAZMATs into the atmosphere. The locations of these facilities have been determined by information obtained from GEPA. For facilities that are permitted to discharge into the water or atmosphere, a 1-mile radius around each facility has also been determined to be the area potentially exposed to a HAZMAT release. As such, the facilities that have the potential to discharge into water encompass 30.7 square miles. Assuming meteorological conditions are not a factor, an area of 29.5 square miles will be affected if a release were to occur from one of the fifteen facilities permitted to discharge to the atmosphere.

- **Hardfill sites**: **Figure D-20** shows the facilities that have the potential for a HAZMAT (fire and toxic gas) release from a hardfill site. The area of susceptibility for this type of release covers an area of 22.3 square miles using a 1-mile radius around each site.
- **Pre-CERCLIS sites**: 409 Pre-Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) sites exist on Guam. Location information is only readily available for some of these sites, and a susceptibility analysis can only be conducted for about one-third of the sites. The amount of other information available for these sites varies. For many of the sites, the types and quantities of HAZMATs are unknown. For many of the sites, the location is known, but the pathway(s) for a HAZMAT release is unknown. Therefore, the susceptibility analysis conducted for the known Pre-CERCLIS sites is very general. The potential area exposed to a HAZMAT release has been determined to be a 1-mile radius around each known site. **Figure D-21** shows the 142 known Pre-CERCLIS facilities and the 1 mile potential exposure area around each location. The area of susceptibility to a HAZMAT release from the known Pre-CERCLIS sites is 139.71 square miles.

Previous Occurrences

No Federal disaster declarations have been made on Guam specifically for a HAZMAT event. The National Response Center collects information on all reported HAZMAT releases. **Table 5-10** lists oil and chemical spills for Guam over a 19-year period. This table was updated for the 2019 Guam HMP by the Guam Environmental Protection Agency and the U.S. Coast Guard Sector Guam utilizing the National Response Center’s database. This information will be updated for the next Guam HMP, if not beforehand.

One of the most significant HAZMAT events to have occurred on Guam happened while Super Typhoon Pongsona was tracking across Guam. During this incident, two petroleum tanks at the Mobil fuel storage facility at the Guam Commercial Port caught fire. The fire burned for 6 days, destroyed four petroleum tanks, and resulted in a temporary halt in civilian gasoline sales. The tank that first caught fire had been damaged during Typhoons Chata’an and Halong, and as a result, standard safety precautions for fuel storage tanks were not followed for this tank prior to typhoon landfall. It is believed that static electricity built up in the tank, causing the fuel vapors in the tank to ignite. The fire deposited a large amount of soot in the adjacent harbor, and the fire retardants used to control the fire may have entered the adjacent marine environment.

Table 5-10 Oil and Chemical Spills, 2000–2019

Type of Incident	Number of Reported Incidents	Medium Affected	Material Name
Aircraft	14	Land, water, nonrelease	Jet fuel and various types of oil
Fixed	197	Air, land, other, soil and water	Anhydrous ammonia, charcoal, chlorine, diesel, hydraulic fuel, jet fuel, polychlorinated biphenyls, radioactive material, total petroleum hydrocarbon, and various types of oil
Mobile	151	Land, subsurface, water and other	Diesel, gasoline, iodine, radioactive material and various types of oil
Pipeline	30	Land, soil, subsurface, water and other	Diesel, jet fuel and various types of oil
Platform	1	Water	Mobile oil
Storage Tank	78	Air, water, land, other, nonrelease and unknown	Anhydrous ammonia, diesel, gasoline, jet fuel, kerosene, refrigerated liquid oxygen, sodium hypochlorite, sulfuric acid and various types of oil
Unknown Sheen	360	Water	Diesel, gasoline and various types of oil
Vessel	414	Air, Water, nonrelease, other, unknown	Ammonia, calcium hypochlorite solution, copper concentrate, diesel, gasoline, jet fuel, phosphoric acid, R-12, and various types of oil

Source: National Response Center 2019.

Probability of Future Events

No comprehensive information is available on the probability of future HAZMAT events across all types of sources (i.e., fixed facilities and transport vehicles). Wide variations in the characteristics of each HAZMAT and between the materials themselves make such an evaluation difficult.

5.3.7 High Surf

Nature

Ocean swells, rough seas, and surf are caused by the fetch of the wind, that is, the area over which a strong wind blows. Swells become fully developed after the wind blows over a sufficient fetch length (roughly greater than 500 miles) for about 24 to 36 hours. Generally, islands in the western Pacific Ocean receive large ocean swells and high surf from the fetch of the wind of nearby tropical cyclones, monsoon surges, and/or distant tropical and extra tropical cyclones. These waves can be over 30 feet in height. On islands surrounded by reefs, high surf hazards are often coupled with extremely strong rip current hazards as seawater and breaks on the reefs, interacts with the coast and rapidly flows through the channels back in to the open ocean.

Tropical cyclones create swells that emanate from the region just outside the cyclone's center or eye. The swells associated with a cyclone generally arrive at a location up to a couple of days ahead of the actual storm. The ocean swell and the high waves at a location increase in size as the storm gets closer. Larger tropical cyclones produce larger swells due to the larger fetch length and width. For storms that pass over or near to an island, the specific locations where devastating waves occur depend on the direction the tropical cyclone is traveling and the track that the storm takes.

Although the hazard of high surf is often associated with tropical cyclones, high surf is not only associated with tropical cyclones. Generally four sources other than nearby tropical cyclones can lead to high surf:

- Swells or a combination of swells and wind waves from easterly trade winds. These generally occur in winter and spring.
- Swells or a combination of swells and wind waves from westerly monsoon winds. These generally occur in summer and fall.
- Swells from distant winter storms near Japan, which occur primarily in winter and spring.
- Swells from slow-moving typhoons that are less than 300 nautical miles away.

Strong monsoon surges can last from a few days to a more than 2 weeks. The persistent southwestern winds of a monsoon surge can produce a long fetch, generating large ocean swells and high surf when they reach land. Swells caused by monsoon surges can combine with swells generated by tropical cyclones; the result can be amplified swell sizes and even higher surf. Generally, this event occurs when a large swell from a monsoon surge travels through the periphery of a tropical cyclone.

The western North Pacific Ocean is susceptible to large ocean swells that have been generated from distant tropical cyclones that will not come near the area. Most commonly these swells occur with large, intense, slow-moving tropical cyclones that take a track west of Guam and south of Japan. These storms generate large swells that can arrive as a surprise because no nearby storm is associated with the high surf.

Location

Tropical cyclones that pass north of Guam generally produce high waves on the northwest coast lines. Tropical cyclones that pass to the southwest or the west of the island can produce high surf and rough seas on the southern and western coasts. A tropical cyclone approaching from the southeast produces hazardous waves on the east and southeast sides of Guam. Westward-moving storms produce the highest surf on the northeast side of the island if they pass over or to the south of the island. Rapidly moving tropical cyclones that pass north of Guam generally do not produce damaging swells on the western side of Guam.

Previous Occurrences

Large ocean swells from passing and distant cyclones, monsoon surges, and trade winds have resulted in hazardous high surf on all coasts of the island. According to the NCDC's Storm Event Database, between 2003 and 2013 high surf, rip currents, and rough seas resulted in 35 deaths and 41 injuries on Guam. Five of these fatalities occurred on June 29, 2004 when three kayaks were overturned by high surf related to Typhoon Tingting, which had passed the Mariana Islands the day before (440 miles north-northwest of Guam).

High surf events can lead to strong rip currents and drownings and to coastal run-up, inundation, coastal erosion, and property damage. Run-up refers to the vertical height of the saltwater on what is normally dry land and inundation refers to the inland distance of the saltwater. High surf (that triggers advisories) on Guam is defined as 9 feet or greater on north, west, and south exposures and 12 feet or greater on eastern exposures. Fifteen (15) feet on any exposure triggers a high-surf warning. Advisory events can last from 2 to 10 days (average duration is 4 days) and warning events can last from 1 to 3 days. Worst conditions usually occur during a new or full moon. The number of days of high surf is not as critical as the number of high-surf events for property damage, because it only takes one short period of flooding to cause property damage. Duration is important for impacts on coastal erosion. **Table 5-11** shows the estimated monthly frequency of high-surf events requiring advisories or warnings.

Table 5-11 Estimated Monthly Frequency of High Surf Event Advisories/Warnings

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
3/1	3/1	3/1	1/0	0/0	0/0	1/0	2/0	3/1	3/1	2/1	3/1	24/7

Source: NCDC 2000.

Super Typhoon Paka, which passed directly over Guam, produced waves ranging from 6 to 30 feet along the northern coast, the entire western coast, and the entire southern coast of Guam. Super Typhoon Pongsona produced waves that were estimated to have been 25 to 30 feet on the high sea cliffs of northeast Guam.

Several occurrences are documented in which the rough seas associated with typhoons that have affected the island have damaged sewage outfall structures, which channel sewer water (with solids removed) to the open ocean. These events have caused treated sewage to drain into the sea at locations much closer to the coastline than the locations of the outfall structures. Damage to outfall pipes occurred during Typhoon Pamela in 1976, Typhoon Dale in 1996, and Super Typhoon Paka in 1997.

Ocean swells caused by monsoon surges can generate high seas and surf as high as 18 to 30 feet. These waves affect the western coast of Guam and have been known to cause coastal erosion and prevent ships from entering or leaving Apra Harbor for long periods. A large wave event between August 11 and 13, 1974, caused by a strong monsoon surge resulted in the sinking of a 700-foot, 40,000-ton passenger liner at the mouth of Apra Harbor. The ocean liner was being towed by an ocean tug to Taiwan for scrap metal, when it sunk near the mouth of the harbor. This multi-day high-surf hazard resulted in more than $4 million in damage.

The high surf events that struck Guam during Typhoon Andy in 1982 and Typhoon Dale in 1996 were believed to have been produced by a combination of monsoon-surge-generated ocean swells and swells generated by the typhoons after they had passed to the west of Guam. The high surf from both of these storms caused large amounts of coastal erosion. The waves from Dale threw large boulders up on the Navy housing area at the Orote Point (80-90 ft. high).

Vulnerable assets include coastal roads, near-shore buried cables, sewer lines and pump stations, and near-coastal buildings. Also see coastal erosion.

Vulnerable jurisdictions include all non-cliff coastal areas. Populated areas are of the greatest risk to the high costs of high surf. High surf associated with typhoons is the most destructive.

Typhoons passing south of the island cause most destruction on the east and south coasts. Typhoons passing north of the island cause most destruction on the west and north coasts. Typhoons passing over the island cause most destruction on all coasts.

Probability of Future Events

As discussed above, high waves on Guam are produced by multiple climatic events. High-wave events with a recurrence interval of less than 20 to 25 years that affect the reefs and open bays on the western side of the island are generally produced by monsoon surges. High waves in this same area with a return period that is greater than 25 years are generally generated by typhoons with a wind intensity of 125 mph or greater. **Table 5-12** illustrates the probability, as calculated by WERI (1999), for waves to affect Guam.

High-wave events along the west-side cliffs are generally produced by monsoon surges up to the point of the 50-year recurrence event, where typhoons again become the dominant high-wave generators for larger-magnitude events.

Table 5-12 Average Recurrence Interval for High Surf on Guam

Average Return Period (Years)	Wave Heights (feet) on East-Side Cliffs	Wave Heights (feet) on East-Side Bays/Reefs	Wave Heights (feet) on West-Side Cliffs	Wave Heights (feet) on West-Side Bays/Reefs
1.0	10	1/<1	-	-
2.0	12	3/1	15	3/1
4.0	15	4/2	20	4/2
10	20	7/4	30	7/4
20	25	10/6	33	10/6
25	27	11/7	35	10/6
50	37	15/9	40	13/8
60	38	17/11	42	14/9
80	40	19/13	44	17/11
100	42	21/14	45	18/12
150	45	22/15	46	19/13
200	47	23/16	47	21/14
300	50	25/16	50	22/15
400	52	28/17	50	24/16
500	54	30/18	50	25/16
600	55	>30/>18	50	27/17

Note: Calculated recurrence intervals included high surf produced by trade winds (waves affecting east-side cliffs) and monsoon-induced waves (waves affecting the western side of the island).
Source: WERI 1999.

5.3.8 Lightning

Nature

Lightning typically occurs as a by-product of a thunderstorm. The rising and descending of air in a thunderstorm separates positive and negative charges, with lightning the result of the buildup and discharge of energy between the areas of positive and negative charge. Water and ice particles can also affect the distribution of the electrical charge. In only a few millionths of a second, the air near a lightning strike is heated to 50,000°F, a temperature hotter than the surface of the sun. Thunder is the result of the very rapid heating and expansion of the air near the lightning, which causes a shock wave.

The hazard posed by lightning is often underrated. High winds, rainfall, and a darkening cloud cover are the warning signs of possible cloud-to-ground lightning strikes. Although many lightning casualties happen at the beginning of an approaching storm, more than half of lightning deaths occur after a thunderstorm has passed. The lightning threat diminishes after the last sound of thunder, but may persist for more than 30 minutes. When thunderstorms are in an area but not overhead, a lightning threat can exist even when skies are clear. Lightning has been known to strike in an area with clear sky more than 10 miles from a storm.

Cloud-to-ground lightning can kill or injure people by direct or indirect means. The lightning current can branch off to strike a person from a tree, fence, pole, or other tall object. Not all people struck by lightning are killed. However, those that survive usually suffer from some effects if the strike. Lightning current can also be conducted through the ground to a person after lightning strikes a nearby tree, antenna, or other tall object. The current can travel through power or telephone lines or plumbing pipes to a person who is in contact with an electric appliance, a telephone, or a plumbing fixture. Lightning can damage property or cause fires through similar processes. Finally, lightning can travel through water, especially through salt water.

In the mid-latitudes, thunderstorms can occur in convective clouds only 20,000 feet deep. However, in the tropics, thunderstorms generally do not occur until cloud tops exceed 45,000-50,000 feet. In the rainy season, the atmosphere can be very unstable, and thunderstorms can grow from a 15,000-foot towering cumulus in less than 1 hour.

Location

On Guam, lightning typically occurs in association with thunderstorm events that are caused by afternoon island warming, large clusters of thunderstorm cells, embedded thunderstorms of moderate and weak monsoon surges, and thunderstorms of tropical cyclones. Storms that result from island heating occur with the greatest concentration near the western coast, from Tumon Bay to Orote Point. These storm events largely depend on the strength and direction of daily wind patterns. Individually isolated lightning and thunderstorm events primarily occur in the early morning hours before sunrise, reflecting the nighttime maxima over the oceans.

Previous Occurrences

In recent history, lightning strikes on Guam have resulted in two fatalities and several fires and power outages. In 2002, residents around the island reported several lightning strikes in association with Super Typhoon Pongsona. In August 2003, an 18-year female tourist was swimming 150-feet offshore of Tumon Bay when she was electrocuted by lightning that struck the water somewhere nearby. In August 2005, lightning damaged a water booster pump station and caused a temporary outage in Yigo and in June 2010 power was lost for some residents in the Yigo area after lightning strikes. In October 2011, a 59-year old man drowned at the Hagatna Boat Basin while fishing. It is suspected that he was electrocuted by lightning that struck nearby.

Vulnerable assets include power distribution system and communications systems. Towers are especially vulnerable to lightning strikes. Also, Guam experiences about 1 death per decade.

Losses include costs to the power and communications industries on Guam amount to about $200,000/year; power surges might cost residents $10,000/year.

Vulnerable jurisdictions include all of Guam where there are power poles and towers or communications towers.

Probability of Future Events

According to the NWS-WFO, Guam experiences more lightning activity than any other place in Micronesia. Thunderstorms generally occur during the wet season, which begins in June and goes through December. During the wet season on Guam, isolated thunderstorms that occur due to island heating are most likely to occur near the western coast in the afternoon hours. **Table 5-13** displays the average monthly frequency of cloud-to-ground lightning on Guam.

Lightning and thunderstorms are also known to occur on Guam, though less often, in the dry season during tropical cyclones, during rare northward spreads of clusters of thunderstorms that occur during breaks in the trade winds, and during "shear line" weather patterns. These are climatic events involving a band of moisture in the tropics that extends from an extratropical (north of the tropics in the western North Pacific Ocean) cold front storm system that traverses the mid-latitudes of the North Pacific. A shear line event usually leads to a strengthening of the trade winds.

Table 5-13 Monthly Frequency of Cloud-to-Ground Lightning on Guam

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
0.7	0.2	0.1	0.6	1.2	3.0	6.0	7.2	7.9	4.2	2.7	0.3	33.9

Source: NCDC 2000.

5.3.9 Non-Seismic Ground Failure (Sinkholes)

Nature

Sinkholes are a characteristic of karst topography; karst geology occurs when rainwater dissolves carbonate rocks, such as limestone, and causes voids, including epikarst, sinkholes, and caves, in the surface and subsurface. Sinkholes are defined as a natural depression or hole in the land formed by the erosion and sometimes the collapse of the underlying rock or soil. Sinkholes are typically caused by the chemical dissolution of underlying carbonate rocks; often, groundwater dissolves the carbonate cement that holds together sandstone particles and then carries away the uncemented particles; this process can form a void. Other formation processes for sinkholes include the collapse of a cave roof and the lowering of the water table. The formation of sinkholes can be facilitated by high groundwater flow, which is often caused by high rainfall.

Location

In 2004, WERI completed a study of the karst features of Guam (WERI 2004). The study showed that northern Guam is almost entirely karst terrain, and the south is mostly volcanic terrain with karst on some outlying limestone units. Accordingly, the vast majority of sinkholes are found in northern Guam. Sinkholes in northern Guam are scattered across the plateau surface, many of which can be seen in the field at Radio Barrigada and off the road toward Ritidian Beach. Of the sinkholes found in southern Guam, the largest concentration is northeast of Fena Reservoir, though significant sinkholes are also found in the southern mountain ridge and the southern part of the eastern coast.

Previous Occurrences

The 2004 WERI study identified 1,252 sinkholes in northern Guam and 197 sinkholes in southern Guam. The sinkholes in northern Guam have depths of over 98 feet and have recorded lengths of hundreds of feet. The largest and deepest sinkholes are found on the Naval Base Ordnance Annex. Since 2004, no further comprehensive studies have been completed. Therefore, no information is available about sinkhole occurrences from 2004 to the present.

Non-seismic ground failures is a rather rare event. Heavy rain events, if precisely focused, can undermine infrastructure such as roads and eventually cause them to collapse. An increase in heavy rain events could increase the risk, but at this time there is no creditable way to predict such an increase.

Vulnerable assets include mostly highways, but could affect houses or other buildings.

Vulnerable jurisdictions include bases of mountains and cliff lines where fast moving water (flash floods) can be focused underneath surface assets.

Probability of Future Events

Recent history and the karst land geology found throughout Guam indicate that sinkholes will continue to occur on Guam. However, due to lack of data, the rate at which sinkholes will develop is unknown.

5.3.10 Salt Spray

Nature

Sea salt deposition can occur throughout Guam. This hazard is primarily caused by tropical cyclones and results from two processes. The first process involves ocean spray that is carried upward by the surface winds of a tropical cyclone to mix with rain. The concentration of salt in rain on Guam is unknown but is detectable. The second process occurs when ocean spray from large waves crashing along the coastal cliffs is blown inland by severe winds. Under this process, the stronger the winds the further inland the sea salt is deposited.

Sea salt deposition can devastate agriculture and other plants, can cause heavy corrosion, and can affect electrical facilities. Some of the effects associated with salt spray (the devastation of agriculture and plants and power outages from shorts in electrical facilities) can be observed almost immediately, but corrosion occurs over a long period, has a cumulative effect on the surface it is affecting, and is difficult to observe immediately after a tropical cyclone.

Location

All of Guam is susceptible to salt spray, but areas near the shore experience the greatest effect.

Previous Occurrences

Little documentation is available regarding historical sea salt deposition events. Because corrosion is difficult to detect immediately after an event and even more difficult to attribute to a specific event, no documentation is available for hazard events that cause corrosion. Therefore, sea salt deposition has likely had a much larger effect than historical hazard events suggest. As WERI (1999) has stated, “It is likely that none of the island escapes the deposition of salt during even a weak tropical storm, but areas near shore feel the greatest effect.” Three historical salt-spray hazard events are described below.

- February 14, 1864: Father Francisco Resano documented that a tropical cyclone caused crop loss due to sea salt deposition.

- November 23, 1992: When the eye of Typhoon Gay crossed Guam, the northern part of the eye-wall sheared off, resulting in little rain falling on the northern part of Guam but very severe winds. Sea salt deposition was heavy across northern Guam. Salt was deposited on power lines, transformers, pumps, generators, vegetation, and most other exposed surfaces. The vegetation of northern Guam was devastated and took nearly 4 years to recover.
- January 24, 2000: "Strong winds caused by a surge in the winter monsoon moved across Guam. Several power outages were reported in the Cabras Island area because of salt spray on insulators."
- January 2015 to July 2019: Guam Power Authority has recorded a total of 8 power outages related to salt spray.

All of Guam is susceptible to salt spray caused by tropical cyclones, monsoon surges, or from easterly trade winds. Most tropical cyclones that pass near Guam are moving in a westward direction. Sixty percent have approached Guam from the east through the southeast, 19 percent have approached from the southeast through the south, and 7 percent have approached from the northeast through the east.

Vulnerable assets include power distribution wires and hardware. Longer-term salt attacks metallic buildings and exposed metal systems such as air conditioners.

Vulnerable jurisdictions include all of the island; coastal areas are more vulnerable than inland areas.

Probability of Future Events

A hazard event from salt spray is related to the combination of high winds, generally from a tropical cyclone, high seas, and low quantities of rainfall. No standard method exists to determine the probability of such an event. As discussed above, historical records of these events are rare (approximately once every 40 to 50 years), but the event is likely underreported.

5.3.11 Sea Level Rise

Nature

With respect to climate change, scientists attribute sea level rise to two different mechanisms: thermal expansion and the loss of land-based ice. Thermal expansion occurs when the ocean water is heated. Warmer sea water takes up more space in the ocean, thereby causing a rise in water level. The melting of land-based ice, such as glaciers and polar ice caps, releases water into the ocean.

Climate change can be described as a change in global or regional climate patterns, attributed largely to the increased levels of atmospheric carbon dioxide produced by the use of fossil fuels. The natural systems consist of warming sea surface temperatures and ocean acidification.

Location

The NOAA Sea Level Rise and Coastal Flooding Impacts Viewer shows that the southern part of Merizo, parts of Inarajan and Hagatna, and a portion of Piti between Naval Base Guam and Cabras Power Plant are most impacted by sea level rise for sea level rise scenarios of 1-6 feet above mean higher high water levels.

The shallow nearshore waters surrounding Guam host approximately 108 km2 of coral reef habitat, with an additional 110 km2 of reef area located greater than 3 nautical miles offshore.

This natural structure reduce the effects of storm surge and coastal erosion by absorbing wave energy during storm events. As waves break on the structure, their energy is reduced, calming waters on the shoreward side of the breakwater and reducing the direct impacts to the shoreline.

Breakwaters are offshore structures designed to limit wave energy by creating a barrier, most often underwater, between open water and the shoreline. While traditional breakwaters may be made from stone, concrete, or other building materials, a living breakwater is a breakwater that is intentionally designed to incorporate natural habitat components while still providing protection to the coastline. On Guam, living breakwaters consist of our coral reefs, which is a natural habitat that provides opportunities for settlement and colonization hard corals or by creating complex structural components that also provide shelter and habitat for various marine and aquatic species.

More than 5,100 species inhabit Guam's coastal waters, including nearly 400 species of stony corals and over 1,000 nearshore fishes. In addition to the value of their biodiversity, coral reefs provide and support numerous ecosystem services, including commercial and subsistence fisheries, tourism, coastal protection, research and education opportunities, and support for social and cultural activities. In the past, nearshore fishing provided a large portion of the CHamoru diet on Guam. Although locally-caught fish are no longer a significant source of food for most residents, Guam's coral reefs are still used for subsistence fishing, some commercial fishing, and recreation by both locals and tourists. Calculating the monetary value of an ecosystem is complex and, in many cases, controversial; however, these valuations provide important metrics for natural resource managers and decision makers. In 2007, the total economic value of Guam's coral reefs was estimated at $169 million per year.

<u>Previous Occurrences</u>

Records and research indicate that the global sea level has been steadily rising at a rate of 0.04 to 0.1 inches per year since 1900. Much of the rise in sea level over this time period has been related to the concurrent rise in global temperature with the consequent thermal expansion of the oceans and accounting for approximately 0.79-2.75 inches of the observed sea level rise while the observed melting of the land-based ice accounting for about 0.79-1.96 inches.

See coastal erosion and high surf. As sea level rises, waves and storm surges will produce greater inundation, even if the strength of events does not change. Most scientists expect a 1-foot rise by 2050. This will at least double the frequency of inundation events from distant storms. However, for tropical cyclone-induced storm surge, the coastal erosion and inundation would more than double.

See high surf and coastal erosion. However, more structures, roads and other infrastructure would be affected. The port and marinas could be impacted as well.

All non-cliff coastal areas, but more destructive on more populated west side coastal areas than east side coastal areas.

Around one fifth of all coral reefs have already been lost and over one quarter of surviving reefs are in danger of imminent decline. Guam's coral reef ecosystems face an array of threats, encompassing both local stressors and the impacts of global climate change and ocean acidification. Stressors include fishing pressures and loss of herbivores, land based sources of pollution, recreational use and misuse, and impacts of climate change and ocean acidification.

Probability of Future Events

According to NOAA, the mean sea level rise trend for Guam is 0.33 inches/year with a 95 percent confidence interval of +/- 0.35 inches/year based on monthly mean sea level data from 1993 to 2006. This sea level rise trend for Guam is equivalent to a change of 2.77 feet in 100 years.

Guam is highly likely to experience a decline in coral health in the future. Actions outlined 2018 Guam Coral Reef Resilience Strategy provide a framework for management and mitigation options to protect this natural infrastructure.

5.3.12 Severe Wind

Nature

Severe wind is often the most destructive part of a typhoon. The strongest winds of a typhoon are generally near the center of the storm. Winds during these storms occur at a sustained level and in gusts. Due to the counter-clockwise rotation of tropical cyclones in the North Pacific Ocean, the speed of storm movement is added to the right side of the storm with respect to its motion. This occurrence creates a semicircle on the right side of the storm, referred to as the "dangerous semicircle," that has stronger winds, and the destructive winds extend farther from the center of the storm on its right side. Therefore, if a typhoon moving from east to west passes to the south of an island, the island will be exposed to the dangerous semicircle and will receive stronger winds than if the same storm were to pass to the north of the island by the same distance.

When tropical cyclones have sustained winds of about 60 mph, an "eye" begins to form at the very center of the storm. Since the winds of a tropical cyclone are circulating around the eye of the storm, the eye has relatively calm winds. The eye-wall is the ring of deep thunderstorm-like clouds that surrounds the eye of a tropical cyclone. The strongest and most destructive winds of a typhoon are in the eye-wall of a storm. The passage of an eye of a typhoon over a particular location produces the greatest possible destructive winds of that typhoon. An eye passage results in the most destructive winds for several reasons:

- The eye-wall contains the maximum winds and most active wind gusts.
- The location of an eye passage will be exposed to nearly the maximum duration of the strongest winds because the eye is at the center of the circulating typhoon and has the maximum diameter of circulation.
- As the eye moves across a location, the winds change in direction, exposing buildings to winds from multiple directions.

The terrain of a landmass can alter the wind patterns of a tropical cyclone. When a tropical cyclone makes landfall on an island such as Guam, generally the speed of the sustained winds of the storm decrease, but the potential peak gusts remain the same speed. The frequency of peak gusts can vary over a landmass and depends on whether the terrain of the landmass is smooth or rough. Smooth terrain experiences a higher frequency of peak gusts than rough terrain. Isolated hills, ridges, and escarpments constitute abrupt changes in the general topography (which is common in several locations on Guam) and cause approaching winds to speed up as they flow up and over the terrain features. The speedup results in increased pressures on buildings. This increase in pressure can reach twice what it will be without the topographic influence. The American Society of Civil Engineers (ASCE) Standard 7-02, *Minimum Design Loads for*

Buildings and Other Structures (ASCE 2002), has a procedure to account for some degree of topography; however, the standard states that the effects of topography for large mountains should be analyzed and modeled by specific location. The modeling of the wind speedup in the mountainous regions of Guam has been proposed by a number of the reports evaluating the typhoon risk and post-disaster effects of storms on Guam.

The western North Pacific Ocean is in an episodal monsoon regime. This monsoonal event occurs when the low-level wind flow in the tropics of this region becomes organized into a defined monsoon trough. This southwesterly low-level wind flow can stretch from the Philippines eastward to the International Date Line. The movements of this monsoonal wind flow are referred to as surges.

Monsoon surges in the area are characterized as weak, medium, or strong. Weak monsoon surges have sustained southwesterly winds of less than 15 mph and a few episodes of heavy rain per day, which often take the form of thunderstorms, over a location. Moderate monsoon surges have more intense southwesterly winds, ranging from 15 to 30 mph, several (three to six) episodes of heavy rain per day, extensive periods of light rain, and heavy overcast skies containing thunderstorms. Strong monsoon surges have gale-force winds (35 to 60 mph), frequent (6 to 12) episodes of heavy rain per day, nearly continuous light rain, and little to no lightning. A strong monsoon surge also has an eastward-moving monsoon squall line, which contains the zone of highest winds and the most extensive monsoon cloudiness. Strong monsoon surges can last from a few days to more than 2 weeks. Weak monsoon surges are most common and strong monsoon surges are least common.

Monsoon surges in the western North Pacific Ocean commonly occur in tandem with tropical cyclones. Although neither weather event is necessarily associated with the other, the superposition of a monsoon surge on a tropical cyclone can increase the amount of rain delivered by the tropical cyclone and extend the size of the area that the tropical cyclone affects. This type of event is more common with weaker tropical cyclones that are more unorganized and may extend much farther from their centers.

Location

Any location on the island has virtually the same chance of experiencing the center of a tropical storm or typhoon and peak wind gusts up to 200 mph. For storms passing south of the island, winds on the east coast (winds blowing toward the coast) would be stronger than winds on the west coast (winds blowing away from the coast). For storms passing north of the island, winds on the west coast (blowing toward the coast) would be stronger than winds on the east coast (blowing away from the coast).

The cliffs on northwest Guam have a tendency to enhance the eye wall convection and cause winds to be a little more intense than would be expected. Thus, while winds in the south-semicircle of the tropical cyclone would normally be weaker than those in the north semicircle, the orographic effects of the island seem to allow the strongest winds to exist in two semicircles: one over Guam and the other in the Rota Channel.

The strongest winds will be in the eye-wall cloud near the windward coast. The winds will generally be weaker on the lee-side coast. Also, as the winds move inland, they weaken. The rougher the terrain, the more the sustained (1-minute average) winds diminish. The vegetation, especially large trees, helps to reduce the winds at the surface. Although the potential peak gust remains the same, the frequency with which the gust gets to the surface is greatly reduced at inland locations. Winds will be stronger along all coasts, at high elevations, along ridge lines, in valleys between hills and mountains, and on sloping terrain.

A simplified wind hazard map (see **Figure D-22**), shows that severe-winds occur in all areas within 500 feet of the coast and at elevations equal to or greater than 300 feet. All other portions of the island are assumed to be in a high-wind hazard zone.

Previous Occurrences

The most destructive winds on Guam have occurred during typhoons and super typhoons. During Guam's most intensive storms, wind-measuring devices tend to fail. However, the strongest wind gust experienced in recent history on Guam is estimated to be nearly 200 mph during Super Typhoon Karen. **Table 5-14a** shows high wind speeds recorded or estimated during typhoon events passing near or over Guam.

Table 5-14 High Wind Speeds Recorded or Estimated during Typhoons, 1950–2019

Typhoon Name	Date	Recorded or Estimated Wind Speeds
Super Typhoon Lola	11/16/1957	97 mph gusts
Super Typhoon Karen	11/11/1962	165 mph sustained, gusts to 195
Typhoon Olive	4/29/1963	100 mph gusts
Typhoon Wendy	7/11/1963	57.6 mph sustained
Tropical Storm Ora	11/23/1968	89 mph gusts
Typhoon Pamela	5/21/1976	159 mph gusts
Typhoon Kim	11/8/1977	89 mph gusts
Typhoon Betty	10/31/1980	91 mph gusts
Typhoon Bill	11/12/1984	97.9 mph gusts
Typhoon Roy	1/12/1988	113 mph gusts
Typhoon Russ	12/20/1990	128 mph gusts
Super Typhoon Yuri	11/27/1991	115 mph gusts
Typhoon Omar	8/28/1992	121 mph sustained, 150 mph gusts
Typhoon Brian	10/21/1992	75 mph sustained, 92 mph gusts
Typhoon Hunt	11/18/1992	75 mph sustained
Typhoon Gay	11/23/1992	98 mph sustained, 121 mph gusts
Typhoon Dale	11/8/1996	104 mph sustained
Super Typhoon Paka	12/16/1997	150 mph sustained, 173 mph gusts
Typhoon Chata'an	7/5/2002	85-90 mph sustained, 105 mph gusts
Typhoon Halong	7/10/2002	100 mph sustained with higher gusts
Super Typhoon Pongsona	12/8/2002	150 mph sustained, 173 mph gusts
Typhoon Tingting	6/27/2004	51 mph sustained, 66 mph gusts
Typhoon Chaba	8/21/2004	58 mph sustained, 79 mph gusts
Typhoon Nabi	08/31/2005	43 mph sustained, 63 mph gusts
Typhoon Sanvu	5/22/2012	52 mph sustained with higher gusts
Typhoon Wipha	10/10/2013	46 mph sustained with higher gusts
Super Typhoon Francisco	10/16/2013	144 mph sustained with higher gusts
Typhoon Tapah	4/27/2014	57 mph sustained with higher gusts
Super Typhoon Neoguri	7/3/2014	52 mph sustained with higher gusts

Table 5-14 High Wind Speeds Recorded or Estimated during Typhoons, 1950–2019

Typhoon Name	Date	Recorded or Estimated Wind Speeds
Super Typhoon Rammasun	7/12/2014	40 mph sustained with higher gusts
Super Typhoon Halong	7/30/2014	63 mph sustained with higher gusts
Super Typhoon Vongfong	10/5/2014	103 mph sustained with higher gusts
Tropical Storm Bavi	3/15/2015	52 mph sustained with higher gusts
Super Typhoon Dolphin	5/15/2015	126 mph sustained with higher gusts
Typhoon Chan-hom	7/5/2015	57 mph sustained with higher gusts
Super Typhoon Soudelor	8/2/2015	126 mph sustained with higher gusts
Typhoon Goni	8/15/2015	80 mph sustained with higher gusts
Typhoon Champi	10/16/2015	69 mph sustained with higher gusts
Typhoon In-Fa	11/20/2015	138 mph sustained with higher gusts
Tropical Storm Fourteen	8/23/2016	46 mph sustained with higher gusts
Typhoon Talim	9/09/2017	40 mph sustained with higher gusts
Typhoon Saola	10/24/2017	46 mph sustained with higher gusts
Super Typhoon Maria	7/4/2018	98 mph sustained with higher gusts
Typhoon Soulik	8/15/2018	40 mph sustained with higher gusts
Super Typhoon Mangkhut	9/10/2018	126 mph sustained with higher gusts
Super Typhoon Trami	9/20/2018	40 mph sustained with higher gusts
Super Typhoon Kong-Rey	9/29/2018	40 mph sustained with higher gusts
Super Typhoon Yutu	10/25/2018	178 mph sustained with higher gusts
Super Typhoon Wutip	2/23/2019	155 mph sustained with higher gusts

Sources: GHS/OCD 2019; NWS-WFO Guam 2019.

Probability of Future Events

Modeling of the recurrence intervals for typhoon-induced sustained wind speeds shows that 75 mph wind speeds occur every 4.1 years, 115 mph wind speeds occur every 16.5 years, 150 mph wind speeds occur every 64 years, and 173 mph wind speeds occur every 175 years.

5.3.13 Slope Failure

Slope failure can lead to a variety of subhazards. For the island of Guam the concerns are with landslides, mudslides, and post-fire debris flows.

Nature

Landslide: Landslides are the dislodging and falling of a mass of soil or rocks along a sloped surface; the dislodged mass itself is also referred to as a landslide. Landslides can be earthquake-induced or non-earthquake-induced. Earthquake-induced landslides occur as a result of ground shaking. The most common earthquake-induced landslides include shallow rock falls, disrupted rock slides, and disrupted slides of earth and debris. Non-earthquake-induced landslides may involve a wide range of combinations of natural rock, soil, or artificial fill. The susceptibility of hillside and mountainous areas to non-earthquake-induced landslides depends on variations in geology, topography, vegetation, and weather. These landslides may also occur due to indiscriminate development on sloping ground or the creation of cut-and-fill slopes in areas of unstable or inadequately stable geologic conditions. Non-earthquake-induced landslides often occur as a result of intense or prolonged precipitation that can saturate slopes and cause failures.

Mudslide: Mudslides are another type of soil failure; mudslides are defined as flows of rivers of liquid mud down a hillside. They occur in relatively steep areas of clay when soils become saturated and moderate to heavy rain is occurring. If no brush, tree, or ground cover is present to hold the soil, mud will form and flow down the slope.

Post-Fire Debris Flow: Post-fire debris flows are defined as fast-moving, highly destructive flows of rain, water, rock, and soil within a burned area and downstream of that area. They are most common in the 2 years after a fire and are usually triggered by heavy rainfall.

The threats of erosion, flooding, and debris flows are significantly increased by the following processes:

- Reduced infiltration and increased runoff: A fire's consumption of vegetative cover increases the exposure of the soil surface to raindrop impact. Soil-heating destroys the organic matter that binds the soil together. Extreme heating may also cause the development of water-repellant, or "hydrophobic," soil conditions, which further reduce infiltration.
- Changes in hill slope conditions: Fires remove obstructions to overland flow, such as trees, downed timber, and plants. The removal of these obstructions can increase flow velocity and therefore erosive power. Increased sediment movement also fills depressions, reducing storage capacity and further contributing to increased velocity and volume of flow. These factors combine to allow more of the watershed to contribute flow to the flood at the same time, and this combination of factors increases the volume of the flood.
- Changes in channel conditions: Increased overland flow and sediment transport result in increased velocity and volume of flow in defined channels. These conditions increase channel erosion and peak discharges.

The occurrence of erosion, floods, and debris flows in burned areas also depends on precipitation intensity—storms with high intensity are more likely to initiate the processes described above and result in flood events. Also, easily eroded types of soils facilitate changes in hill slope conditions and increase the volume of runoff.

In extreme situations, the conditions described above combine to form a post-fire debris flow. These flows are often the most destructive events resulting from heavy rainfall in fire-affected areas. They occur with little warning, carry vast quantities of rock and other material, and strike objects with extreme force. Because of their viscosity and density, debris flows can move or carry away objects as large as vehicles and bridges, and they can travel great distances down canyons and stream valleys. Debris flow fronts can travel at high speeds, exceeding 50 miles per hour. In most cases, only large basins designed specifically to trap these flows are capable of resisting the forces that accompany them.

Location

Landslide: An adequate landslide inventory map is not available for Guam. Therefore, the most appropriate way to identify where landslide hazards occur on Guam is to determine the susceptibility of an area based on the geologic units mapped at the surface.

Susceptibility to landslide hazards on Guam has been determined by the geology and the slope angle of the various specific areas on the island. Using these two factors, a quantitative rating of the potential of an area for a landslide to occur was defined. As shown on **Figure D-23**, all slopes with an angle of 30 percent or more are considered to have a moderate to high potential for a landslide to occur. All slopes that have a slope of less than 5 percent are considered to have a low potential, regardless of the geologic deposits present. As such, Yona, Santa Rita, Piti, Asan/Maina, Talofofo, Inarajan, Merizo, Umatac, and Agat all have proportionally large areas with a moderate, a moderate to high, or a high potential for landslides to occur. Only the relatively flat areas along the eastern coast of this half of the island and the flat areas around Apra Harbor have a low potential for landslides.

It is important to note that this simplified assessment does not include some potentially important factors, such as local geologic structures. Many of the landslides triggered during the August 3, 1993, earthquake were associated with faults. When the orientation of potential landslide failure planes (such as bedding or fault planes) is favorable for failure with respect to the slope, landslides can occur in geologic units not generally prone to fail, particularly during earthquakes or when the ground is saturated.

Mudslide: The areas most susceptible to mudslides are steep areas made of clay, areas where mudslides occurred before but bedrock is not yet exposed, and sloped clay areas where vegetation has been removed. Steep refers to angles that range from 10 degrees from the vertical to about 40 degrees from the vertical. For angles of less than 10 degrees from the vertical, water flows over the clay and forms waterfalls. For angles greater than 40 degrees from the vertical, gravity does not normally cause the mud to give way. As such, Nimitz Hill, Santa Rita, the Cross Island Road, and the southern mountain areas are the most susceptible mudslide locations on Guam.

Post-Fire Debris Flow: Land that is adjacent to or downslope of recently burned areas is susceptible to potentially hazardous debris flows. Areas susceptible to recent burn and potential debris flow include localities on the west coast, such as Agat and Umatac, and the areas near Talofofo, Inarajan, and Merizo.

Previous Occurrences

Landslide: Available historical records of landslides due to earthquakes document that landslides resulted from the earthquakes that occurred on September 22, 1902; October 30, 1936; November 1, 1976; and August 8, 1993. Many of the landslides that occurred during the large 1993 earthquake are well documented. For example, a large landslide was observed along a remote sea cliff on the northeast side of Guam near Lajuna Point. This slide was not known to result in any damage. Many relatively smaller slides were observed on steep cut-slopes and limestone cliffs throughout the island. Several of these landslides occurred immediately adjacent to areas of dense development. Several slopes failed and several slopes were heavily destabilized along Marine Corps Drive in an area of commercial buildings. Landslides in this area crushed two cars. The steep face of a large quarry pit failed, causing the deformation of a large building on the flat ground surface above the slope, which was underlain by fill material. Many of the slide areas were observed to coincide with the location of limestone fault zones.

Typhoons also lead to landslides in Guam. Although these events are not highly documented, records show that rain from Typhoon Chata'an resulted in numerous landslides.

Mudslide: Similar to landslides, the occurrence of mudslides in Guam is not well documented. However, records indicate that mudslides occurred in the unpopulated mountainous areas of Guam during Typhoon Chata'an.

Post-Fire Debris Flow: Previous occurrences of post-fire debris flows have not been documented on Guam to date.

Extent and Vulnerable Jurisdictions: Slope failure here is generally addressed as mud slides. These occur in steep areas (within a 40-degree angle from the vertical) made of clay soil. Once the soil is saturated, continued heavy rain can cause slope failure.

Vulnerable jurisdictions include steep areas along the Cross Island road, Santa Rita, Nimitz Hill Estates, and southern mountains. This becomes more threatening as people dig into clay hillsides to build houses.

Probability of Future Events

Landslide: The probability of future landslides is unknown. However, landslides are likely to result from large earthquakes felt on Guam (3-5 years) and tropical cyclones and typhoons (on average, three tropical cyclones and one typhoon pass within 180 nautical miles of Guam each year).

Mudslide: The probability of future mudslides is unknown. However, mudslides are likely to occur after tropical cyclones and typhoons (on average, three tropical cyclones and one typhoon pass within 180 nautical miles of Guam each year), and other prolonged or intense rainstorm events which generally occur during the wet season from June – December.

Post-Fire Debris Flow: Post-fire debris flows are most common in the 2 years after a fire; they are usually triggered by heavy rainfall. Flooding and increased runoff may continue for several years after a fire, but it is unusual for post-fire debris flows to be produced beyond the second rainy season after a wildfire. Some of the largest debris-flow events have been triggered by the first intense rainstorm of the storm season. However, because a number of complex factors lead to debris flow (rainfall, wildfire, and slope and soil conditions), the probability of future post-fire debris flows on Guam is unknown.

5.3.14 Terrorism

Nature

No universally accepted definition of terrorism is available; however, the Code of Federal Regulations defines terrorism as "... the unlawful use of force and violence against persons or property to intimidate or coerce a government, the civilian population, or any segment thereof, in furtherance of political or social objectives." In general, terrorism is seen as violence against civilians to achieve a political or ideological objective through fear.

Terrorism can occur in various forms: assassinations; kidnappings; hijackings; bomb scares and bombings; cyber attacks (computer-based); and the use of chemical, biological, nuclear, and radiological weapons. Concern is also growing about emerging infectious diseases and the possibility of a bioterrorism attack.

A bioterrorism attack is the deliberate release of viruses, bacteria, or other germs (agents) to cause illness or death in people, animals, or plants. These agents are typically found in nature, but it is possible that they can be modified to increase their ability to cause disease, make them resistant to current medicines, and/or to increase their ability to be spread into the environment. Biological agents can be spread through the air, through water, or in food. Terrorists may use biological agents because they can be extremely difficult to detect and do not cause illness for several hours or several days. Some bioterrorism agents, like the smallpox virus, can be spread from person to person and some, like anthrax, cannot.

Location

The Department of Homeland Security's National Planning Scenario identifies the possible terrorist strike locations it views as most plausible. Places in Guam judged to be at risk include cities, such as Dededo and Tamuning/Tumon; places that have economic and symbolic value, such as Agana Heights and Yigo; places with hazardous facilities; and areas where large groups of people congregate, such as office buildings and sports arenas. However, it is also believed that terrorists may begin to target small rural communities, with the goal of targeting pesticide facilities, chemical plants, the water supply, dams, or agriculture.

Previous Occurrences

No major terrorist events have occurred on Guam. In December 2010, one report from a supposedly credible source noted the threat of a possible terrorist attack on Guam in the form of food poisoning aimed at hotels and restaurants. According to the report, the terrorist plot was aimed at attacking hotels and restaurants at multiple locations across the United States over a single weekend. However, no attacks occurred.

Probability of Future Events

Due to the large number of factors involved in terrorism, including the many factors involved in human decision-making and motivation, the probability of a future terrorist attack on Guam is unknown.

5.3.15 Transportation Accident

Nature

In this Guam HMP, a transportation accident is defined as an accident involving an aircraft or marine vessel that causes a large loss of life, a large loss of property, or has a drastic effect on the economy. Marine and air transit, through Apra Harbor and GIAA, respectively, are almost the only means for people and goods to enter or leave Guam. (Additional airports are located on the military bases on Guam.) An accident that involves an airplane or a marine vessel has the potential to have a significant effect on the economy and infrastructure of Guam. An accident involving a large commercial passenger airplane or a large marine passenger vessel also has the potential to result in a large number of fatalities or injuries to the people on the airplane or marine vessel as well as the people on the ground at the site of an airplane crash.

An airplane crash can lead to a large number of fatalities or injuries to persons on the airplane and persons on the ground at the site of the accident. This type of accident could also cause a large loss of property. A crash at the GIAA could lead to a disabling of the operational facilities at the airport and could cause this port of entry to close temporarily. Any size or type of aircraft can cause damage, injuries, and fatalities on the ground at the site of a crash. The amount of damage at a crash location is related to the location of the accident and the nature of the crash.

A large airplane accident can have indirect economic effects on Guam. For example, 99.1 percent of tourists entering Guam arrive by air, and a large passenger airline crash could dramatically affect Guam's tourist economy by scaring tourists from traveling to Guam. A crash that disables the functionality of the international airport can drastically reduce the movement of goods and people to and from the island, leading to a large negative economic effect. A crash into a populated area can affect the economy and social health of that particular area.

Aircraft accidents can be caused by mechanical failure, manufacturing error, pilot error, air traffic controller error, natural hazards, and inappropriate cargo. While aircraft can also clearly be used for terrorism, it is beyond the scope of this study to address acts of terrorism. Mechanical failures and manufacturing errors can cause an aircraft to function improperly and crash. Pilot and air traffic controller errors can lead to mid-air collisions and crashes into the ground or an elevated structure. Natural hazards, such as wind shear, terrain-induced turbulence, and poor visibility, can lead to the loss of control of an aircraft or an incorrect judgment by a pilot. Inappropriate cargo, such as a pressurized container, can lead to sudden explosions and loss of control of an aircraft. Also, an aircraft accident can be caused by several of these factors that cumulatively lead to loss of control of an aircraft and a crash.

A transportation accident involving marine vessels can result in a large loss of life or a large loss of property and can have an adverse effect on the economy of Guam. This type of accident could also have an indirect adverse effect on the economy by leading to a temporary decrease in tourism and the temporary loss of the shipment goods. Approximately 80 percent of Guam's food supplies and 95 percent of Guam's goods are delivered to Guam on marine vessels. Between Fiscal Year 2007 and Fiscal Year 2012, the Port Authority of Guam (PAG) averaged 2,011,084 revenue tons of cargo. In addition to the loss of property, a collision involving an oil tanker can result in a large environmental impact and an indirect economic impact due to a temporary shortage in oil and oil-based products (e.g., gasoline) on the island. Vessel collisions can occur if a vessel runs aground or onto a reef, if the vessel collides with another vessel, or if a vessel collides with a stationary facility in Apra Harbor.

Depending on where it occurs, a vessel collision can lead to additional indirect effects. For example, a collision in the shipping lanes of Apra Harbor can cause part or the entire harbor to be blocked. This type of event would affect both the Commercial Port of Guam and military operations based in Apra Harbor. This event can adversely affect Guam's economy because the movement of goods via the port will be halted. If the accident is severe, it could take a long time to clear the blockage of the shipping lanes.

Accidents involving marine vessels can be caused by errors in operating the vessels, communication errors between vessel operators and port operators, mechanical errors on the vessels, and natural hazards. Also, a combination of these factors can lead to a marine vessel accident. Natural hazards, like high winds or high surf, combined with errors in vessel operation or mechanical errors, can lead to a loss of control of a vessel. In addition, vessels that are not adequately moored and anchored can be displaced and potentially collide with something during a hazard event (e.g., a typhoon).

Location

Marine and air transit locations and routes, through Apra Harbor and GIAA, are shown on **Figures D-24 and D-25**. As shown on this figure, many residential and commercial land uses are located near the airport. An accident where a plane misses a runway could mean a large area of damage and devastation in these areas of intensive land use. The GIAA is also located close to the populated areas of the Agana, Agana Heights, Barrigada, Chalan Pago-Ordot, Mangilao, Mongmong-Toto-Maite, and Tamuning/Tumon villages. An aircraft crash into any of these areas could also have a very large impact.

Previous Occurrences

Two aircraft transportation accidents have occurred on Guam involving large commercial airlines. On August 6, 1997, a Boeing 747 operated by Korean Air, struck Nimitz Hill and crashed 3 miles short of the GIAA. Of the 254 persons on-board the airplane, only 29 survived the accident. The investigation conducted by the National Transportation Safety Board (NTSB) concluded that the probable cause of the accident was "the captain's failure to adequately brief and execute the nonprecision approach and the first officer's and flight engineer's failure to effectively monitor and cross-check the captain's execution of the approach. Contributing to these failures were the captain's fatigue and Korean Air's inadequate flight crew training. Also, contributing to the accident was the Federal Aviation Administration's (FAA's) intentional inhibition of the minimum safe altitude warning (MSAW) system at Guam and the agency's failure to adequately manage the system." The combination of this aviation accident and a general economic recession in South Korea resulted in an 87 percent decline in the number of Korean tourists that visited Guam between 1997 and 1998. The available records did not describe the effects to the uninhabited area where the plane crashed.

On December 17, 2002, a Philippine Airlines Airbus A330 struck the power lines on top of Nimitz Hill. This accident resulted in no injuries or fatalities. Although the investigation by the NTSB was not as thorough as the investigation for the Korean Air accident, the NTSB has stated that the probable cause of this incident was "the pilot's initiation of a premature descent that was both below the nominal glideslope and steeper than normal. Contributing to the incident was the air traffic controller's failure to respond to the MSAW warning and issue a safety alert as required by FAA order."

No documentation of a marine vessel accident resulting in a blockage of Apra Harbor is readily available. Historical records show several marine vessel accidents during tropical cyclones that have resulted in large property damage. As discussed in **Section 5.3.15** (Tropical Cyclone), tropical cyclones generally have very high winds, high surf, and elevated sea levels, all of which can affect marine vessels. During Super Typhoon Karen in 1962, three ships sank, and two tugboats and a huge floating crane were pulled off their moorings and driven ashore. No records of the financial losses for these accidents were available. During Tropical Storm Mary in 1974, high winds caused the Caribia, a 40,000-ton passenger liner being towed to Taiwan for salvage, to be cut loose from its tugboat at the entrance to Apra Harbor. As a result, the ship ran aground on the breakwater of the harbor and sank. This accident resulted in a $3.3 million loss. During Super Typhoon Pamela in 1976, ten ships and tugboats sank or ran aground in Apra Harbor. No records of the financial losses for these accidents were available. During Typhoon Russ in 1990, two ships broke from their moorings in Apra Harbor and went aground on the harbor breakwater. No records of the financial losses for this accident were available. Although not directly stated in historical records for most of these storms, these accidents were likely due to the high winds and improper anchoring or mooring of the vessels prior to landfall of the storms.

Probability of Future Events

The FAA has many rules and regulations to minimize the potential for airline accidents to occur. After the Korean Air accident, the NTSB made many recommendations specific to the GIAA to improve the safety for large commercial airplanes using this airport. The near-tragic accident of the Philippines Airlines Airbus in 2002 demonstrated that these types of accidents are repeatable. Also, this accident brought to light that the FAA and the GIAA had not acted on many of the NTSB recommendations that resulted from the Korean Air accident.

No standard method has been developed to predict the probability of an airplane transportation accident on Guam.

5.3.16 Tropical Cyclone

Nature

A tropical cyclone is a general term for an intense, circulating storm that covers all of the following terms: tropical depression, tropical storm, typhoon, and super typhoon.

Tropical cyclones occur over tropical and subtropical oceans. These storms are low-pressure weather systems that range in size from 120 to 1,500 miles across. In the northern hemisphere, the low-level winds of a tropical cyclone blow counter-clockwise around a center of organized, deep thunderstorms, where the strongest winds generally reside. The various names or classifications for tropical cyclones relate to the intensities of the storms:

- A tropical depression has maximum sustained winds of 38 mph. A tropical depression has a closed circulation. The Joint Typhoon Warning Center generally issues warnings when the circulation reaches 29 mph.
- A tropical storm has maximum sustained winds in the range of 39 to 73 mph.
- A typhoon has maximum sustained winds in the range of 74 mph or greater.
- A super typhoon is a special class of typhoon that has maximum sustained winds of 150 mph or greater.

The size and intensity of a tropical cyclone are not related. Small, very intense typhoons and large, relatively weak typhoons are possible. A large-diameter tropical cyclone may miss a landmass by a large distance and still result in heavy rains and high winds on the landmass, but the center of the storm, which is where the storm is most intense, would have missed the landmass. A small-diameter tropical cyclone of the same intensity needs to make a direct or nearly direct hit on a landmass to cause substantial damage. In this situation, the center of the small-diameter tropical cyclone would have hit or nearly hit the landmass, likely resulting in heavy damage.

Tropical cyclones can occur at any time in the western North Pacific Ocean, and the route or track that a tropical cyclone follows can vary. These storms can intensify rapidly or remain at a relatively low intensity (i.e., remain a tropical depression) for their whole existence. To a certain extent, meteorologists can forecast the track that a tropical cyclone will likely take, the intensity of a tropical cyclone when it makes landfall, and the amount of time a tropical cyclone will take to make landfall, but many exceptions and errors can occur in forecasting for a tropical cyclone.

The disastrous effect of tropical cyclones on islands in the western North Pacific Ocean can be subclassified into several hazards causing widespread damage. Each of the following hazards that may be associated with a tropical cyclone is addressed separately and can be found in the following sections.

- Section 5.3.1 (Coastal Erosion)
- Section 5.3.5 (Flooding)
- Section 5.3.7 (High Surf)

- Section 5.3.10 (Salt Spray)
- Section 5.3.11 (Severe Wind)
- Section 5.3.12 (Slope Failure)

Location

All of Guam is susceptible to a tropical cyclone. Most tropical cyclones that pass near Guam are moving in a westward direction. Sixty percent have approached Guam from the east through the southeast, 19 percent have approached from the southeast through the south, and 7 percent have approached from the northeast through the east.

Previous Occurrences

Guam is located in an area of the western North Pacific Ocean known as "Typhoon Alley." Thirty-three percent of the world's cyclones develop in the immediate area around Guam. Guam has been affected by approximately 202 tropical cyclones from 1900 to 2013. Although records prior to 1946 are likely incomplete, approximately 85 of these tropical cyclones, at least 61 of which were typhoons or super typhoons, have made landfall onto Guam and have resulted in severe winds, heavy rainfall, or flooding. Presidential Disaster Declarations have been made for six tropical cyclones: Typhoon Russ, Super Typhoon Yuri, Super Typhoon Paka, Typhoon Chata'an, Super Typhoon Pongsona, and Typhoon Tingting. Historical records from 1900 to 2013 have accounted for 86 fatalities and 461 injuries from tropical cyclone–related and monsoon-related hazards.

Table 5-14b Tropical Cyclones within Radius of 180 Nautical Miles from Guam and with Minimum Intensity of 39 mph, 2010–2019

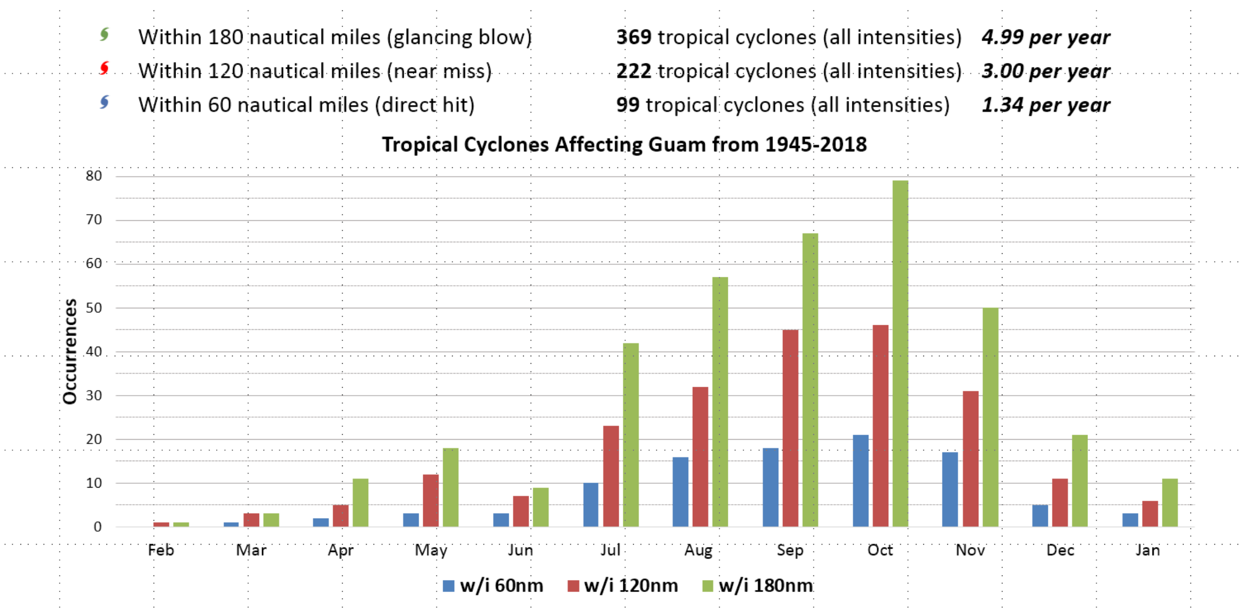
Typhoon Name	Date	Distance at CPA (NM)	Intensity at CPA	Maximum Intensity within Radius
Typhoon Sanvu	5/22/2012	47.1	46 mph	52 mph
Typhoon Wipha	10/10/2013	18.5	23 mph	46 mph
Super Typhoon Francisco	10/16/2013	50.3	34 mph	144 mph
Typhoon Tapah	4/27/2014	134.3	46 mph	57 mph
Super Typhoon Neoguri	7/3/2014	146.9	46 mph	52 mph
Super Typhoon Rammasun	7/12/2014	21.4	34 mph	40 mph
Super Typhoon Halong	7/30/2014	46.1	63 mph	63 mph
Super Typhoon Vongfong	10/5/2014	62.5	103 mph	103 mph
Tropical Storm Bavi	3/15/2015	5.8	46 mph	52 mph
Super Typhoon Dolphin	5/15/2015	45.5	115 mph	126 mph
Typhoon Chan-hom	7/5/2015	26.7	52 mph	57 mph
Super Typhoon Soudelor	8/2/2015	120.4	103 mph	126 mph
Typhoon Goni	8/15/2015	66.7	63 mph	80 mph
Typhoon Champi	10/16/2015	144.1	63 mph	69 mph
Typhoon In-Fa	11/20/2015	152.8	126 mph	138 mph
Tropical Storm Fourteen	8/23/2016	47.4	46 mph	46 mph
Typhoon Talim	9/09/2017	78.0	29 mph	40 mph
Typhoon Saola	10/24/2017	128.2	46 mph	46 mph
Super Typhoon Maria	7/4/2018	13.3	63 mph	98 mph

Table 5-14b Tropical Cyclones within Radius of 180 Nautical Miles from Guam and with Minimum Intensity of 39 mph, 2010–2019

Typhoon Name	Date	Distance at CPA (NM)	Intensity at CPA	Maximum Intensity within Radius
Typhoon Soulik	8/15/2018	53.4	28 mph	40 mph
Super Typhoon Mangkhut	9/10/2018	51.1	115 mph	126 mph
Super Typhoon Trami	9/20/2018	29.7	28 mph	40 mph
Super Typhoon Kong-Rey	9/29/2018	69.5	40 mph	40 mph
Super Typhoon Yutu	10/25/2018	108.8	178 mph	178 mph
Super Typhoon Wutip	2/23/2019	144.1	155 mph	155 mph

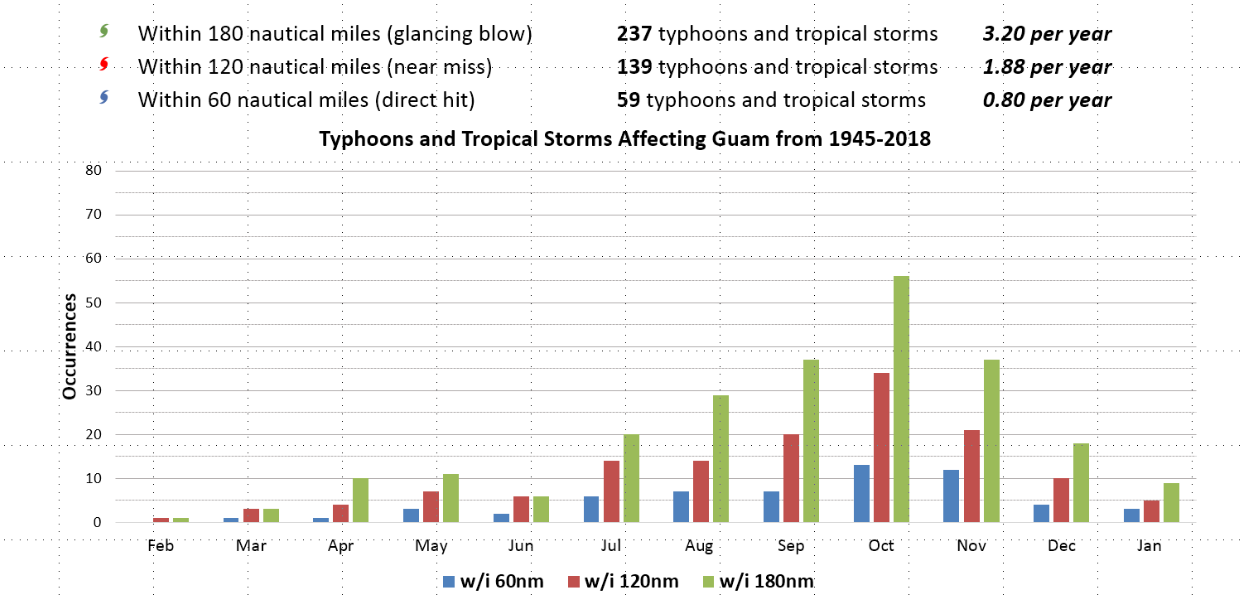
Sources: GHS/OCD 2019; NWS-WFO Guam 2019; JTWC Best Track 2019.

Graph 5-1 Number of Tropical Cyclones within 60, 120, and 180 Nautical miles of Guam by Month from 1945-2018



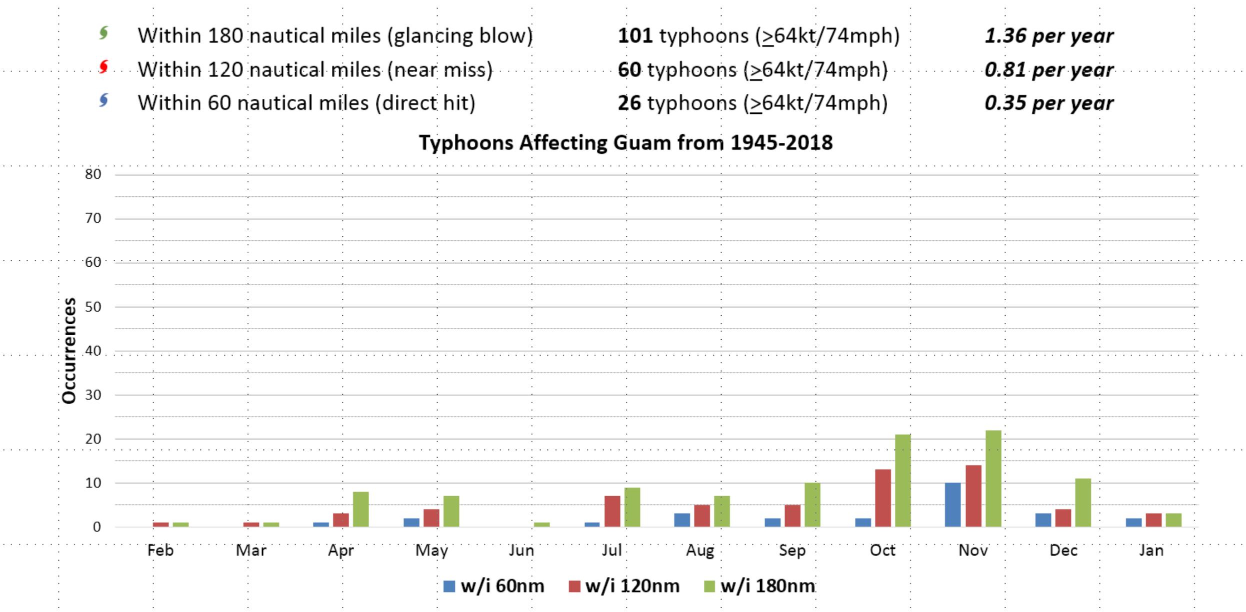
Source: NWS-WFO Guam 2019.

Graph 5-2 Number of Typhoons and Tropical Storms within 60, 120, and 180 Nautical miles of Guam by Month from 1945-2018



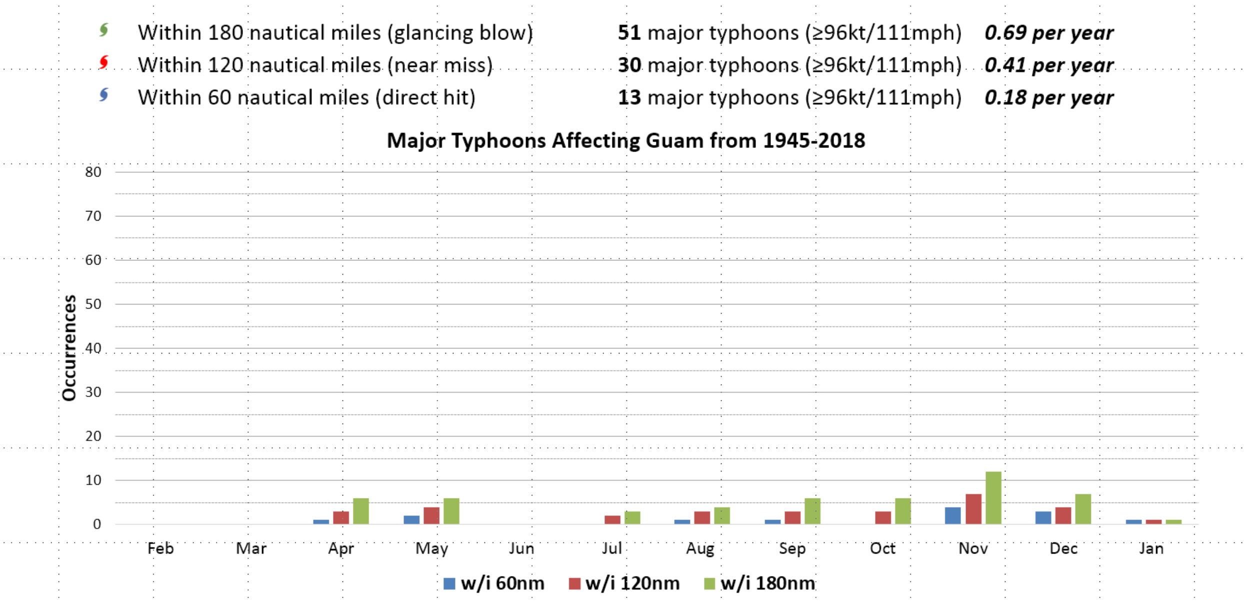
Source: NWS-WFO Guam 2019.

Graph 5-3 Number of Typhoons within 60, 120, and 180 Nautical miles of Guam by Month from 1945-2018



Source: NWS-WFO Guam 2019.

Graph 5-4 Number of Major Typhoons within 60, 120, and 180 Nautical miles of Guam by Month from 1945-2018



Source: NWS-WFO Guam 2019.

Probability of Future Events

Historical data show 12 typhoons passing over Guam between 1923 and 2002 in which the eye of the storm passed over the island. This methodology assumes that the most devastating typhoons to have struck Guam occur when the eye of a typhoon passes over the island. However, several of the typhoons with very high recorded wind speeds on Guam did not have their eye pass over the island. For instance, the eye of Typhoon Dale (1996) did not pass over Guam, but it produced 98 mph sustained winds. Typhoon Kim in 1977, whose eye passed over Guam, had sustained winds recorded at 89 mph.

In WERI (1999), a risk assessment was conducted for the probability and magnitude of tropical cyclones to occur on Guam primarily using the HURISK (Hurricane Risk) Model. The HURISK Model was developed in 1987 for the NWS-WFO Tropical Prediction Center at Miami, Florida. The model uses multiple inputs (including the historical tracks of tropical cyclones, the radius of their maximum winds, the time and location of their landfall, and the rate of storm decay after landfall). HURISK has been modified for the western North Pacific Ocean and is currently the most developed and comprehensive model for tropical cyclone risk for the area. WERI used a relatively comprehensive dataset of 1,469 storms that occurred near Guam during the period 1945 through 1997.

WERI (1999) determined that a 73.8 percent chance existed that a tropical storm or typhoon will come within 86 miles of Guam with sustained winds of readily 40 mph for any year, and a 46.3 percent chance of a typhoon for any given year. Within any 5 years, a 99.9 percent probability exists that a tropical cyclone will come within 86 miles of Guam with at least sustained winds of 40 mph, and a 95.6 percent probability of a typhoon occurrence for any given year.

In expressing typhoon recurrence through wind speeds, the average return period for minimally strong typhoon-induced sustained winds to be experienced on Guam (i.e., approximate sustained wind speeds of 75 mph) will be 4.4 years. The approximate sustained wind speed of a 100-year storm on Guam was calculated to be approximately 160 mph, a 50-year storm was calculated to have approximate sustained wind speeds of 150 mph, and a 20-year storm was calculated to have a sustained wind speed of approximately120 mph. Therefore, a 20-year storm would carry the intensity of Typhoon Omar in 1992 and a 50-year storm would roughly carry the intensity of Super Typhoon Paka in 1997 or Super Tyhoon Pongsona in 2002.

It should be noted that the risk assessment performed by WERI did not include storm events from more recent years, such as Typhoon Chaba, Typhoon Tingting, Typhoon Chata'an, Typhoon Halong, and Super Typhoon Pongsona. It is likely that the inclusion of these more recent intense typhoon events would change the probability and magnitude calculations performed by WERI. However, currently, the risk assessment performed by WERI is the best and most comprehensive forecast performed to date.

5.3.17 Tsunami Inundation

Nature

A tsunami is a series of traveling ocean waves of extremely long length generated by disturbances associated primarily with earthquakes occurring below or near the ocean floor. Subduction zone earthquakes at plate boundaries often cause tsunamis. However, tsunamis can also be generated by submarine landslides, submarine volcanic eruptions, the collapse of volcanic edifices, and in very rare instances, large meteorite impacts in the ocean.

As an oceanic plate is subducted beneath a continental plate, it sometimes brings down the lip of the Continental Plate with it. Eventually, too much stress is put on the lip and it snaps back, sending shockwaves through the earth's crust; these shockwaves cause a tremor under the sea, known as an undersea earthquake. Factors that affect tsunami generation from an earthquake event include magnitude (generally, a 7.5 M and above), depth of event (a shallow marine event that displaces the seafloor), and type of earthquake (thrust as opposed to strike-slip).

In the deep ocean, the length of a tsunami from wave crest to wave crest may be a hundred miles or more but has a wave height of only a few feet or less. Thus, the wave period can be up to a little more than an hour and wavelengths can exceed several hundred miles. Thus, tsunamis are unlike typical wind-generated swells on the ocean, which might have a period of about 10 seconds and a wavelength of up to 300 feet. Tsunamis cannot be felt aboard ships in the open ocean, nor can they be seen from the air in the open ocean. In deep water, the waves may reach speeds exceeding 700 miles per hour.

Tsunamis reaching heights of more than 100 feet have been recorded. As a tsunami wave approaches the shallow coastal waters, it appears normal and its speed decreases. Then as the tsunami nears the coastline, it can grow to a great height, smash into the shore, and cause much destruction.

Tsunamis not only affect beaches that are open to the ocean, but also bay mouths, tidal flats, and the shores of large coastal rivers. Tsunami waves can also diffract or "wrap" around land masses. Because tsunamis are not symmetrical, the waves can be much stronger in one direction than another, depending on the nature of the source and the surrounding geography. However, tsunamis propagate outward from their source, so coasts in the shadow of affected land masses are usually fairly safe.

Tsunamis can originate hundreds or even thousands of miles away from coastal areas. Local geography may intensify the effect of a tsunami. Areas at greatest risk are less than 50 feet above sea level and within 1 mile of the shoreline. Tsunamis arrive as a series of successive “crests” (high-water levels) and “troughs” (low-water levels). These successive crests and troughs can occur anywhere from 5 to 90 minutes apart. They usually occur 10 to 45 minutes apart.

Tsunami run-up occurs when a peak in the tsunami wave travels from the near-shore region onto shore. Run-up is usually expressed in meters above normal high tide. Except for the largest tsunamis, such as the 2004 Indian Ocean event, tsunamis generally do not result in giant breaking waves (like normal surf waves at the beach that curl over as they approach shore). Rather, they come in much like very strong and fast-moving tides (i.e., strong surges and rapid changes in sea level). Much of the damage inflicted by tsunamis is caused by strong currents and floating debris. Tsunamis often travel much farther inland than normal waves. Most deaths during a tsunami result from drowning. Associated risks often include flooding, polluted water supplies, and damage to structures and utilities, which can lead to fires.

Location

Figure D-26 shows the potential areas for tsunami inundation. These areas include all land masses below 16.4 feet in mean sea elevation and the inundation areas for the five bays (Apra Harbor, Tumon Bay, Pago Bay, Agana Bay, and Inarajan Bay) listed in the tsunami hazard assessment study completed by the Pacific Risk Management `Ohana, the Pacific Marine Environmental Laboratory Center for Tsunami Research, and the NWS-WFO Pacific Services Center (PSC) in October 2009.

Previous Occurrences

Historical data regarding tsunami events on Guam are minimal and likely incomplete. The general view is that tsunamis occur infrequently on the island and that the band of coral reefs surrounding the island forms a natural barrier against destructive tsunamis. It is likely that tsunami events are underreported because Guam frequently experiences large wave run-up during typhoon events, and the tsunami run-up on Guam may be less damaging than the wave run-up associated with typhoons.

Historical documentation shows that 12 tsunami events have affected Guam. **Table 5-15** shows the details of these recorded tsunami events. The largest documented tsunami was in 1849, with a vertical wave run-up of 11.4 feet. The most recently documented tsunami occurred after the August 8, 1993, earthquake. The only recorded damage was that a truck parked on the beach in Pago Bay was struck by a wave and a car in Ylig Bay was washed into the ocean. No other tsunami activity was recorded on Guam from this earthquake.

Table 5-15 Historical Tsunami Inundations on Guam, 1819–2019

Date	Vertical Run-up (feet)	Earthquake Location	Magnitude
1819	N/A	Mariana Islands	N/A
01/24/1849	11.4	Mariana Islands	7.5

Date	Vertical Run-up (feet)	Earthquake Location	Magnitude
05/16/1892	N/A	Guam, Mariana Islands	7.5
02/1903	N/A	Philippines	N/A
12/09/1909	N/A	Guam, Mariana Islands	8
03/04/1952	0.3	Se. Hokkaido Island, Japan	8.1
10/04/1952	0.3	Kamchatka, Russia	8.2
03/09/1957	0.3	Central Aleutian Islands, Alaska	8.3
05/22/1960	0.3	Central Chile	8.6
10/13/1963	0.3	Kuril Islands, Russia	8.1
03/28/1964	0.3	Gulf Of Alaska-Alaska Pen.	8.5
08/08/1993	N/A	Guam, Mariana Islands	7.8
02/27/2010	1.27	Maule, Concepcion, Talcahuano, Chile	8.8

Source: NGDC/WDS Tsunami Runup 2019.

Probability of Future Events

The probability of a tsunami is generally expressed as the potential of a return period and the wave run-up elevation with a 1 percent chance of being equaled or exceeded in any given year. Because of the limited historical data, a return period and the elevation of a tsunami with a 1 percent annual chance of occurring have not been and cannot be established for Guam. However, the available historical information and reported regional considerations, such as the band of coral reef around the island and the steep bathymetry surrounding the island, which would lower the risk of significant wave run-up, demonstrate that the possibility of a large tsunami causing extensive damage is generally low. Despite this, a large, locally-generated tsunami hit American Samoa in Sept. 29, 2009, killing 34 people. American Samoa has many of the same characteristics as Guam and a similar occurrence could take place on Guam.

5.3.18 Wildland Fire

Nature

A wildland fire is a type of wildfire that spreads through consumption of vegetation. It often begins unnoticed, spreads quickly, and is usually signaled by dense smoke that may be visible from miles around. Wildland fires can be caused by human activities (such as arson, hunting or campfires) or by natural events such as lightning. Wildland fires often occur in forests or other areas with ample vegetation. In addition to wildland fires, wildfires can be classified as urban fires, interface or intermix fires, and prescribed fires.

The following three factors contribute significantly to wildland fire behavior and can be used to identify wildland fire hazard areas.

- **Topography:** As slope increases, the rate of wildland fire spread increases. South-facing slopes are also subject to more solar radiation, making them drier and thereby intensifying wildland fire behavior. However, ridgetops may mark the end of wildland fire spread, since fire spreads more slowly or may even be unable to spread downhill.
- **Fuel:** The type and condition of vegetation plays a significant role in the occurrence and spread of wildland fires. Certain types of plants are more susceptible to burning or will burn with greater intensity. Dense or overgrown vegetation increases the amount of combustible

material available to fuel the fire (referred to as the “fuel load”). The ratio of living to dead plant matter is also important. The risk of fire is increased significantly during periods of prolonged drought as the moisture content of both living and dead plant matter decreases. The fuel’s continuity, both horizontally and vertically, is also an important factor.

- **Weather:** The most variable factor affecting wildland fire behavior is weather. Temperature, humidity, wind, and lightning can affect chances for ignition and spread of fire. Extreme weather, such as high temperatures and low humidity, can lead to extreme wildland fire activity. By contrast, cooling and higher humidity often signal reduced wildland fire occurrence and easier containment. Strong winds can also carry burning embers farther downwind, igniting new fires.

The frequency and severity of wildland fires is also dependent on other hazards, such as lightning, drought, and infestations. If not promptly controlled, wildland fires may grow into an emergency or disaster. Even small fires can threaten lives and resources and destroy improved properties. In addition to affecting people, wildland fires may severely affect livestock and pets. Such events may require emergency watering/feeding, evacuation, and shelter.

In addition to stripping the land of vegetation and destroying forest resources, large, intense fires can harm the soil, waterways, and the land itself. Soil exposed to intense heat may lose its capability to absorb moisture and support life. Exposed soils erode quickly and enhance siltation of rivers and streams, thereby enhancing flood potential, harming aquatic life, and degrading water quality. Lands stripped of vegetation are also subject to increased debris flow hazards.

Wildland fires begin at an ignition source. Ignition sources can be natural, such as lightning; intentional human activity, such as arsonists; or unintentional human activity, such as uncontrolled campfires. Fires are not a natural occurrence on Guam. On Guam, lightning has the potential to start wildland fires, but is generally associated with heavy rain and high humidity, which is not meteorologically conducive to starting fires. Arson is a common cause of wildland fires on the island. Local hunters use fire to clear sightlines and draw deer and pigs into the open, farmers sometimes burn fields to clear them, and homeowners will burn savanna to create firebreaks around their residences.

If not promptly controlled, wildland fires may grow into an emergency or disaster. Even small fires can threaten lives, resources, and destroy improved properties. In addition to affecting people, wildland fires can severely affect livestock and pets. Such events may require the emergency watering/feeding, shelter, evacuation, and event burying of animals.

The indirect effects of wildland fires can also be catastrophic. As stated above, fires are not a natural occurrence on the island, which means that the native ecosystem is poorly adapted to burning. Thus, the native forests can be devastated by a wildland fire because the native forests plants are not adapted to revegetate after a fire. Native forestlands that have been heavily burned are often revegetated by grassland savanna. Many of these grassland plant species are nonnative species that are well adapted to repeated burning. The introduction of fire-adapted grass species to Guam has resulted in the promotion of fire on the island. When the grasses become dry during the dry season, they develop into an excellent fuel source. In addition, when grasslands that are adjacent to forests burn, the forest edge is typically burned back, promoting revegetation by the nonnative fire-adapted grasses. This event results in an expansion of the spatial extent of the grassland and a reduction in the size of the native forest.

Wildland fires have also contributed to a chronic erosion problem on Guam, especially on the southern half of the island. Soil exposed to intense heat may lose its capability to absorb moisture and support life. Exposed soils erode quickly and enhance siltation of rivers and streams. Erosion and siltation enhance the potential for flooding, harming aquatic life (especially the coral reefs surrounding the island), and degrading water quality. Lands stripped of vegetation are also subject to increased landslide hazards and can become incapable of revegetating. The accumulation of upland sediment onto the coral reefs of Guam is believed to be a large threat to the viability of these reefs. The die-off on the reefs off southwestern Guam has been attributed to the covering of the reef by eroded topsoil. Due to the economic link between Guam's coral reefs and tourism, recreational fishing, subsistence fishing, and shoreline protection, the degradation and loss of these coral reefs have been linked to the lowering of the quality of life on Guam.

Location

High and very high wildland fire hazard areas on Guam are shown on **Figure D-27**. This figure was developed using a fuel model, as shown in **Table 5-16**. For this model, the fuel type and critical weather frequency were determined to be the most important factors in influencing the location and severity of a wildland fire. Critical weather frequency was considered a constant. As shown on **Figure D-27**, the most concentrated areas that are susceptible to wildfires are the northern and northwestern portion of the island. Priority areas for fuel treatments to reduce risk of fire damage to standing forests are shown on **Figure D-28**. Fire risk to forests and urban environments was determined by calculating a 300 ft. buffer distance from all forest edges. These buffers were chosen as areas most likely to have "edge effects" for fire risk to standing forests. The total area of fire behavior risks (0-3) was calculated within each zone for all watersheds. Yellow and red colors highlight areas of moderate and high risk; their proximity to forest edges identifies these areas as high priority for fuel breaks and conversion to forest. At watershed scales, the eastern watershed management areas contribute the largest number of acres that pose a moderate or higher fire risk within this forest edge interface zone (8,187 acres), mostly relegated to the central uplands in Talofofo, Ylig and Pago, with upper reaches of Apra in the western watershed management area. Though smaller in land area, the western watersheds all exhibit approximately one-quarter of the land area having moderate or higher fire risk to standing forests, including the Manelle (Merizo) watershed, which contains a marine preserve at the outlet of the watershed.

Table 5-16 Wildland Fire Fuel Model

Fuel Type	Fuel Sources	Hazard Area
Heavy	Round wood 3-8 inches in diameter	Very High
Medium	Round wood consisting of 1/3 to 3 inches in diameter	High
Light	Herbaceous plants and round wood less than ¼ inch in diameter	Moderate

Source: BSP 2004.

Previous Occurrences

The NCDC's Storm Event Database documents significant wildland fire events occurring in January, February, March and April of 1998. The high number of fire incidents during this several month timeframe was attributed to a very wet El Niño season in 1997 that was followed by a meteorological drought and heavy fuel loads from trees damaged by Super Typhoon Paka. During this period, approximately 1,400 fires burned 13,000 acres. One thousand residents were forced to evacuate, one home was reported destroyed, and $250,000 in damage was reported. On

March 23, 1998, approximately 1,000 acres were burned. On March 23, 1998, the fire suppression efforts to fight the Tiyan and Toto Complex fires were authorized by FEMA to receive fire suppression funding, under the declaration, FEMA-2197-DR-GU. The most recent wildland fire event documented on the NCDC's Storm Even Database in Guam is a wildland fire event in May of 2001 in Barrigada that led to one injury.

Climate change has been increasing the length of the fire season, the size of the area burned each year and the number of wildfires on Guam. Drier conditions and higher temperatures on Guam increase not only the likelihood of a wildfire to occur, but also the duration and the severity of the wildfire. Fires can be beneficial for the ecosystems, but changes in climatic conditions are allowing them to burn out of control. Wildfires pose risks to human life, property and infrastructures. Forest fires directly kill plants and animals, also causing a loss of habitat.

Probability of Future Events
Wildland fires are more likely to occur during the 6-month dry season from December to May. The number and size of fires are likely to increase during droughts that follow El Niño seasons.

5.4 INVENTORY ASSETS

The third step in the risk assessment process is the identification of assets that may be affected by hazard events. As discussed in detail in **Section 4.8** (Assets), the inventory of assets is divided into the following three major categories:

- Population
- EFMUTS
- GBS

5.5 VULNERABILITY ANALYSIS

The fourth step in the risk assessment process is the vulnerability analysis and potential loss estimates. The intent here is to identify potentially vulnerable assets, estimate potential losses associated therewith.

For this Guam HMP, the vulnerability analysis consists of five steps, including the actual analysis, as follows:

- Asset inventory
- Methodology
- Data limitations
- Vulnerability analysis
- Summary of impacts

The DMA 2000 requirements for assessing vulnerability by jurisdiction and state facility are shown below. Vulnerability refers to the susceptibility of people, buildings, and infrastructure to physical injury, harm, damage, or economic loss from a hazard.

DMA 2000 REQUIREMENTS – RISK ASSESSMENT – ASSESSING VULNERABILITY

Assessing Vulnerability

Requirement § 201.4(c)(2)(ii): *[The State risk assessment **shall** include an] overview and analysis of the State's vulnerability to the hazards described in this paragraph (c)(2), based on estimates provided in local risk assessments as well as the State risk assessment. The State shall describe vulnerability in terms of the jurisdictions most threatened by the identified hazards, and most vulnerable to damage and loss associated with hazard events. State owned critical or operated facilities located in the identified hazard areas shall also be addressed.*

DMA 2000 REQUIREMENTS – RISK ASSESSMENT – ASSESSING VULNERABILITY BY JURISDICTION

Element

A. Does the new or updated plan describe the State's vulnerability based on estimates provided in local risk assessments as well as the State risk assessment?
B. Does the new or updated plan describe the State's vulnerability in terms of the jurisdictions most threatened and most vulnerable to damage and loss associated with hazard event(s)?
C. Does the updated plan explain the process used to analyze the information from the local risk assessments, as necessary?
D. Does the updated plan reflect changes in development for jurisdictions in hazard prone areas?

DMA 2000 REQUIREMENTS – RISK ASSESSMENT – ASSESSING VULNERABILITY OF STATE FACILITIES

Element

A. Does the new or updated plan describe the types of State owned or operated critical facilities located in the identified hazard areas?

Source: FEMA 2008.

DMA 2000 REQUIREMENTS – RISK ASSESSMENT – ESTIMATING POTENTIAL LOSSES

Estimating Potential Losses

Requirement § 201.4(c)(2)(iii): *[The State risk assessment **shall** include an] overview and analysis of potential losses to the identified vulnerable structures, based on estimates provided in local risk assessments as well as the State risk assessment. The State **shall** estimate the potential dollar losses to State owned or operated buildings, infrastructure, and critical facilities located in the identified hazard areas*.

DMA 2000 Requirements – Risk Assessment – Estimating Potential Losses by Jurisdiction

Element

A. Does the new or updated plan present an overview and analysis of the potential losses to the identified vulnerable structures?
B. Are the potential losses based on estimates provided in local risk assessments as well as the State risk assessment?
C. Does the updated plan reflect the effects of changes in development on loss estimates?

DMA 2000 REQUIREMENTS – RISK ASSESSMENT – ASSESSING LOSSES OF STATE FACILITIES

Element

A. Does the new or updated plan present an estimate of the potential dollar losses to State owned or operated buildings, infrastructure, and critical facilities in the identified hazard areas?

Source: FEMA 2008.

5.5.1 Asset Inventory

Assets that were included in the 2014 and 2019 Guam HMP's vulnerability analysis are as follows and shown in **Figures D-5 through D-11**. **Tables E-1 through E-4** lists the specific critical facilities and infrastructure by category, name and location.

- Population of 159,358
- General building stock of 39,953 units
- 850 EFMUTS owned and operated by the Government of Guam as well as the private sector (see **Section 4.8** [Assets] for additional information).

5.5.2 Methodology

Hazards United States – Multi-Hazard (HAZUS-MH) is FEMA's recommended risk assessment software program for earthquakes, flooding, and severe winds. However, as of this planning update, HAZUS-MH is not available for Guam. Without HAZUS-MH, the vulnerability analysis for Guam is much more difficult and, in some ways, less precise as will be possible using HAZUS-MH.

In the absence of HAZUS-MH, vulnerability analysis for all versions of the Guam HMP has been conducted using a quantitative analysis in GIS. A quantitative vulnerability analysis uses detailed information on hazard location and probability/magnitude (where possible). A quantitative analysis was conducted for seismic hazards (faults, liquefaction), flooding, HAZMAT, sea level rise, severe wind, slope failure (landslide), tsunami inundation, and wildland fire. Tropical cyclone was analyzed through the analysis of the key subhazards associated with tropical cyclone, including flooding and severe wind.

A quantitative analysis was not conducted on coastal erosion; disease; drought; stormwater flooding; high surf; lightning; non-seismic ground failure; salt spray; sea level rise, slope failure (mudslide and post fire debris flow); terrorism; and transportation accident (aviation and port) due to lack of data to conduct such an analysis. GHS/OCD plans to conduct a vulnerability analysis for sea level rise when the data becomes available for download from the National Oceanic and Atmospheric Administration (NOAA). Likewise, a quantitative vulnerability analysis has not been prepared for HAZMAT sewage discharge because the sewage is discharged directly into the ocean and therefore does not affect the assets and population on land.

The quantitative analysis for the 7 hazards identified above was conducted in GIS by overlaying each hazard area identified in **Section 5.3** (Hazard Profiles) on top of the assets identified in **Section 4.8** (Assets). The results of the exposure analyses were tabulated at the Territory-level in **Tables 5-17 through 5-18** and at the village level, as shown in **Appendix F (**Vulnerability Analysis Results by Village).

5.5.3 Data Limitations

The exposure analyses used in this plan are subject to the following limitations:

- In the case of population, no estimates of injuries or deaths are made and no estimates of the value of lives/injuries are made

- In the case of EFMUTS and GBS, it is assumed that the entire structure value is lost (i.e., no loss damage curves or worst-case scenario).
- No contents values are estimated for EFMUTS or GBS
- No loss of function costs are estimated for EFMUTS or GBS
- No displacement or temporary quarters costs are estimated for EFMUTS or GBS

5.5.4 Vulnerability Analysis

Vulnerable population, GBS and EFMUTS at risk to each identified hazard are listed in **Tables 5-17 and 5-18** as well as **Appendix F** (Vulnerability Analysis Results by Village). A detailed summary of this analysis is provided in **Section 5.5.5** (Summary of Impacts).

Table 5-17 Summary All-Hazard Vulnerability Analysis for Guam: Total

Hazard*	Subhazard	Hazard Zone	Area Affected Square Miles	Population No.	Essential Facilities, Major Utilities, and Transportation Systems (EFMUTS): Essential Facilities No.	Essential Facilities Value ($)	Major Utilities No.	Major Utilities Value ($)	Transportation Systems – Facilities No.	Transportation Systems – Facilities Value ($)	GBS No.	GBS Value ($)
Total Potential			208.9	159,358	348	$903,518,667	361	$883,648,209	114	$110,814,438	39,953	$6,106,136,529
Earthquake	Fault Proximity		45.86	29,634	71	168,903,633	83	177,165,550	43	13,028,925	6,385	1,104,513,017
Earthquake	Liquefaction	Very High	0.51	266	15	13,678,834	2	132,319,860	6	56,032,379	205	47,800,150
Earthquake	Liquefaction	High	2.49	1,462	11	61,481,476	11	72,299,956	13	11,579,684	379	62,598,251
Flooding	100-year floodplain		10.4	7,555	76	134,680,102	27	45,891,651	40	76,916,320	2,182	397,939,267
HAZMAT	NPDES-Air Permit	Air Pathway	29.37	34,147	142	227,196,269	99	504,395,431	58	13,461,264	12,344	2,230,722,200
HAZMAT	NPDES-Water Permit	Water Pathway	30.63	23,549	107	190,705,727	75	416,455,139	58	91,531,545	13,661	1,890,492,898
HAZMAT	Hardfill Sites	Air Pathway	22.33	22,518	74	56,675,818	48	57,701,041	31	6,807,736	8,424	1,030,379,181
HAZMAT	Pre-CERCLIS Facilities	Air, Water, Unknown	139.62	118,555	301	852,305,930	251	707,188,704	124	108,526,413	30,206	3,529,706,065
Severe Wind		Extreme	115.86	84,197	131	521,458,018	217	527,126,809	52	86,723,585	18,660	1,435,767,315
Slope Failure		Land-slide – Very High	46.65	13,593	13	9,067,514	18	63,907,455	16	2,903,397	603	75,261,984
Slope Failure		Land-slide – High	8.93	2,598	18	8,251,967	35	68,684,213	7	2,213,947	1,127	90,509,638
Tsunami Inundation		Water Level at 16 feet above MSL	11.74	8,046	93	173,284,314	46	282,402,438	52	88,508,439	3,270	555,841,911
Wildland Fire		Very High	82.66	58,108	36	103,027,401	90	143,151,601	33	6,189,662	7,948	975,330,739
Wildland Fire		High	82.3	52,021	109	257,712,447	149	317,517,696	40	5,905,588	13,661	1,890,492,898

* Due to a combination of a lack of adequate information and the lack of a standard methodology for a quantitative vulnerability analysis, vulnerability analysis results have not been prepared for **Tables 5-17 and 5-18** for the following hazards: coastal erosion; disease; drought; stormwater flooding; high surf; lightning; non-seismic ground failure; salt spray; sea level rise; slope failure (mudslide and post fire debris flow); terrorism; and transportation accident (aviation and port). Although vulnerability analysis results have not been prepared for tropical cyclone, the following key subhazards caused by tropical cyclone are included: flooding and severe wind. A quantitative vulnerability analysis for sea level rise was not included in this HMP due to lack of immediate data availability and time constraint. In addition, a quantitative vulnerability analysis has not been prepared for HAZMAT sewage discharge because the sewage is discharged directly into the ocean and therefore does not affect the assets and population on land.

Table 5-18 Summary All-Hazard Vulnerability Analysis for Guam: Proportion

					Essential Facilities, Major Utilities, and Transportation Systems (EFMUTS)							
			Area Affected	Population	Essential Facilities		Major Utilities		Transportation Systems – Facilities		GBS	
Hazard*	Subhazard	Hazard Zone	% of Square Miles	% of No.	% of No.	% of Value ($)	% of No.	% of Value ($)	% of No.	% of Value ($)	% of No.	% of Value ($)
Total Potential			99.56	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.71	99.77
Earthquake	Fault Proximity		21.86	18.60	20.00	18.64	22.93	20.02	32.33	11.56	15.94	18.05
	Liquefaction	Very High	0.24	.17	4.23	1.51	0.55	14.95	4.51	49.71	0.51	0.78
		High	1.19	.92	3.10	6.79	3.04	8.17	9.77	10.27	0.95	1.02
Flooding	100-year Floodplain		4.96	4.74	21.41	14.86	7.46	5.19	30.08	68.24	5.45	6.50
Hazardous Materials	NPDES-Air Permit	Air Pathway	14.00	21.43	40.00	25.08	27.35	57.00	43.61	11.94	30.81	36.45
	NPDES-Water Permit	Water Pathway	14.60	14.78	30.14	21.05	20.72	47.06	43.61	81.21	34.09	30.89
	Hardfill Sites	Air Pathway	10.64	14.13	20.85	6.26	13.26	6.52	23.31	6.04	21.02	16.84
	Pre-CERCLIS Facilities	Air, Water, Unknown	66.54	74.40	84.79	94.07	69.34	79.92	93.23	96.29	75.38	57.67
Severe Wind		Extreme	55.22	52.84	36.90	57.55	59.94	59.57	39.10	76.95	46.57	23.46
Slope Failure		Land-slide Very High	22.23	8.53	3.66	1.00	4.97	7.22	12.03	2.58	1.50	1.23
		Land-slide High	4.26	1.63	5.07	0.91	9.67	7.76	5.26	1.96	2.81	1.48
Tsunami Inundation		Water Level at 16 feet above MSL	5.60	5.05	26.20	19.13	12.71	31.91	39.10	78.53	8.16	9.08
Wildland Fire		Very High	39.40	36.5	10.14	11.37	24.86	16.18	24.81	5.49	19.84	15.94
		High	39.22	32.6	30.70	28.44	41.16	35.88	30.08	5.24	34.09	30.89

* Due to a combination of a lack of adequate information and the lack of a standard methodology for a quantitative vulnerability analysis, vulnerability analysis results have not been prepared for **Tables 5-17 and 5-18** for the following hazards: coastal erosion; disease; drought; stormwater flooding; high surf; lightning; non-seismic ground failure; salt spray; sea level rise; slope failure (mudslide and post fire debris flow); terrorism; and transportation accident (aviation and port). Although vulnerability analysis have not been prepared for tropical cyclone, the following key subhazards caused by tropical cyclone are included: flooding and severe wind. A quantitative vulnerability analysis for sea level rise was not included in this HMP due to lack of immediate data availability and time constraint. In addition, a quantitative vulnerability analysis has not been prepared for HAZMAT sewage discharge because the sewage is discharged directly into the ocean and therefore does not affect the assets and population on land.

5.5.5 Summary of Impacts

A summary of impacts (i.e., percentage at risk) for the population, GBS and EFMUTS for each identified hazard in the 2014 Guam HMP is provided below. Change in development within each hazard area is discussed in terms of: population percentage increase or decrease within a village and the number and percentage of total building permits issued within a village in 2013. In addition, RL properties are discussed in this section.

Earthquake: Fault Proximity (Surface Fault Rupture)
Similar to results from earlier versions of the Guam HMP, a moderate percentage of Guam's population (18.6 percent) was found to be directly exposed to surface faulting while a similar proportion of the GBS was exposed at about 16 percent, or 6,385 buildings. In addition, 71 Essential Facilities (worth $168.9 million), 83 Major Utilities (worth $177.2 million), and 43 Transportation Systems (worth $13.0 million) are located in this hazard area.

The assessment of the vulnerability to surface faulting represents an overemphasis of the hazard because a larger area has been determined to be exposed than actually will be exposed and because the analysis assumes all characterized faults to rupture across the island at the same time. Two different data sources of surface fault locations often characterize different faults and different fault locations. Research has not been conducted to verify which dataset of faults is correct. In addition, the location of these surface faults has not been specifically characterized. Therefore, to remain conservative in assessing Guam's vulnerability, both datasets are used and a 984-foot buffer around each fault is used to describe the exposed area.

As shown in **Tables F-3 and F-4**, in terms of village-level population exposed to surface faulting, Tamuning/Tumon has 6,008 people (30.52 percent) followed by Dededo with 3,805 (8.47 percent). Both of these communities had the greatest number of people in this hazard area in the 2011 Guam HMP. Both of these areas experienced grew between 5 – 10 percent during a 10 year period (2000 – 2010), which is greater than the average island population growth change of 2.9 percent during this timeframe.

Exposure of the Essential Facilities is spread throughout all affected villages. The village with the most exposure of Essential Facilities is Hagatna, with 25 facilities that are worth $17.8 million. In addition, the most concentrated number of exposed Major Utilities are located in Yigo (16 facilities valued at $28.6 million), Tamuning/Tumon (10 facilities valued at $34.5 million), and Dededo (10 facilities worth $13.0 million). Hagatna and Tamuning/Tumon also have the most concentrated number of Transportation Systems, with 7 facilities valued at $5.9 million and 7 facilities valued at $2.0 million, respectively.

In terms of village-level GBS exposure, Yigo has the highest number of exposed GBS with 1,065 (21.7 percent of village structures) worth $97.7 million. In this hazard area, Tamuning/Tumon has 942 GBS (26.6 percent) worth $388.7 million and Santa Rita has 786 GBS (29.5 percent) worth $61.9 million. In 2018, the greatest number of building permits (93 permits or 25.8 percent of the total permits issued) were issued in Dededo.

Earthquake: Liquefaction
Similar to the earlier versions of the Guam HMP, a relatively small population of 1,728 people (approximately 1.0 percent) on Guam currently resides in areas with very high or high levels of exposure to liquefaction, as shown in **Tables 5-17 and 5-18**. The percentage of EFMUTS located in areas with very high or high levels of exposure is also relatively low with 26 Essential

Facilities (worth $75.2 million), 13 Major Utilities (worth $204.6 million), and 19 Transportation Systems (worth $67.6 million). The exposed GBS is also relatively low with 584 structures (1.5 percent), valued at $110.4 million.

The high value of the Transportation Systems located in the hazard area is due to the location of port facilities in Apra Harbor. In addition to the potential costs of replacement of the facilities at the port, irreparable damage to these facilities could severely affect all movement of goods on and off Guam. A value for the normal and daily functions of these facilities has not been assessed for this analysis, but would be a secondary potential effect of this hazard event.

Similar to earlier versions of the Guam HMP, and shown in **Tables F-5 to F-**7, in terms of village-level population exposed to very high and high liquefaction hazard, Santa Rita leads with 497 people (approximately 8.0 percent of the village population), followed by Tamuning/Tumon (553 people, 2.81 percent of the village population) and Dededo and Hagatna (164 and 163, respectively). During the past two Census reporting periods, Santa Rita and Hagatna have experienced a decline in population (-18.9 percent and -4.5 percent of the village population, respectively) while Tamuning/Tumon and Dededo have experienced a population increase (9.3 percent and 4.6 percent, respectively

Exposure of the EFMUTS by number of facilities is concentrated in Hagatna village, with 14 Essential Facilities that are worth $12.5 million, as shown in **Tables F-5 to F-8**. Only 13 Major Utilities (seven in Piti) and 19 Transportation Systems (six in Hagatna and five in Piti) are located in high and very high liquefaction areas.

The village-level exposure of GBS is concentrated in three villages: Santa Rita with 213 structures worth $16.8 million, Piti with 187 structures worth $26.7 million, and Hagatna with 128 structures worth $44.5 million. Only 11 building permits were issued in these villages in 2018 (3 percent of the total number of building permits issued in 2018).

Flooding: Coastal and Riverine

The 2007 Guam FIRM was used to determine the Special Flood Hazard Area (SFHA). As such, the population on Guam that is located in the 100-year floodplain consists of 7,555 people (4.74 percent), as shown in **Tables 5-17 and 5-18** and **Table F-9** (**Appendix F [**Vulnerability Analysis Results by Village]). The percentage of people in this hazard area is nearly the same as in previous versions of the HMP. A similarly small proportion of Guam’s GBS is exposed to the floodplain with 2,182 buildings (5.5 percent), worth $397.9 million. A larger portion of EFMUTS is exposed with 143 facilities (16.8 percent), worth $257.5 million.

A large portion of the exposed EFMUTS facilities are located adjacent to Apra Harbor and are a part of the port facilities. As such, a total of 40 facilities (30.1 percent) in Transportation Systems, worth $76.9 million, are exposed to a flood. Though it is unlikely that a flood would completely destroy some of the large facilities at the port, such as the cranes used to load and unload cargo, the potential exposure of these facilities to flood shows that a flood could affect the regular functions of these facilities. If a flood affects the functions at the port in Apra Harbor, the movement of goods on and off the island would be affected. A value for the normal and daily functions of these facilities has not been assessed for this analysis, but disruption of these functions would be a secondary potential effect of this hazard event.

In terms of village-level population exposure, as shown in **Tables F-9 and F-10**, Tamuning/Tumon has 1,900 people (9.65 percent of the village population) residing in the SFHA while Mongmong-Toto-Maite has 1,275 people (18.68 percent of the village population). Both Tamuning/Tumon and Mongmong-Toto-Maite experienced population increases (9.3 percent and 16.8 percent of the village population) well above the island average of 2.9 percent from 2000 – 2010.

Exposure of the EFMUTS is concentrated in Hagatna with 35 facilities (mostly Essential Facilities) worth $26.0 million. Piti and Tamuning/Tumon follow with 21 exposed facilities each, worth $99.0 million in Piti and $73.8 million in Tamuning/Tumon.

Hagatna has 402 GBS structures (64.0 percent of the village GBS), worth $139.8 million, that are exposed to a flood hazard. Agat has 364 exposed structures (26.7 percent of the village GBS) with a value of $31.0 million. Merizo has 372 exposed structures (55.2 percent of the village GBS), and their value is $30.6 million. Only 6 building permits were issued for Hagatna, 7 building permits in Agat in 2018, and no building permit was issued in Merizo during this time period.

RL properties are properties that suffer from repeated flooding. FEMA defines a RL property as a property with at least two $1,000 claims within any 10-year period since 1978. **Table 5-19c** and **Figure D-30** show that as of June 30, 2012, there are 15 RL properties are on Guam. **Table 5-19a** shows that that as of April 30, 2019, and for the 2014 Guam HMP, there were 16 RL properties on Guam. No actions have been taken to mitigate these properties to date. There were attempts to elevate certain RL properties. However, due to the type of building construction on Guam, they were not cost efficient. However, a mitigation action has been included for this Guam HMP to address RL properties (see **Section 6.5** [Mitigation Actions] for additional information).

Table 5-19a Repetitive Loss Properties

Guam Repetitive Loss Community Summary, as of April 30, 2019

The data on this report contains repetitive loss properties only. Mitigated properties (properties that are no longer repetitive) are not included in the counts.

RL Buildings Total	Total	Guam Grand Total
RL Buildings Total	16	16
RL Buildings Insured	2	2
RL Loses Total	35	35
RL Losses Insured	6	6
Total Loss Amount	$643,364.91	$643,364.91
Total Loss Amount Insured	$187,512.62	$187,512.62
Properties with 4+ Losses	0	0
Insured Properties with 4+ Losses	0	0
Properties w/ 2-3 Losses > Total Value	1	1
Insured Properties w/ 2-3 Losses > Total Value	0	0
Building Post-Firm A-V Zone	1	1
Insured Building Post-Firm A-V Zone	0	0

Source: FEMA NFIP 2019.

Table 5-19b Repetitive Loss Properties

Guam Repetitive Loss Properties, as of April 30, 2019

Property Locator	Property Location	Most Recent Date of Loss
33033	Homigneros Maya	10/7/1985
95517	Old Agat	12/15/1997
105261	Merizo	7/30/1999
119361	Piti	12/8/2002
119363	Agat	7/5/2002
122527	Tumon	12/8/2002
	Tumon	12/8/2002
	Tumon	12/8/2002
122528	Sinajana	12/8/2002
	Chalan Pago	12/8/2002
	Sinajana	11/27/1991
	Sinajana	11/27/1991
122529	Dededo	12/16/1997
	Tamuning	12/7/2002
	Tamuning	12/16/1997
122532	Inarajan	12/8/2002
122728	Tumon	12/8/2002
122731	Agat	8/15/2011
122733	Agat	12/8/2002
122734	Piti	12/8/2002
122738	Apurguan	12/8/2002
128732	Umatac	6/18/2004
136741	Agat	10/12/2004
212572	Agana	9/10/2018
	Agana	8/28/2011
237864	Agat	9/19/2013

Source: FEMA NFIP 2019.

Table 5-19c Repetitive Loss Properties

Guam Repetitive Loss Properties, as of 2012

Property Location	Property Type	Flood Insurance	Number of Losses	SFHA
Agana	Single Family	Yes	Unknown	Yes
Agat	Single-family	Yes	2	Yes
Agat	Single-family	Yes	2	No
Agat	Single-family	No	2	Unknown
Agat	Single-family	No	2	Yes
Agat	2 – 4 family home	No	2	Yes
Apurguan	Single Family	Yes	Unknown	Yes
Inarajan	Single-family	Yes	2	Yes
Merizo	Single-family	No	2	Yes
Old Agat	2 – 4 family home	NO	Unknown	No
Piti	Nonresidential	No	2	Yes
Piti	Single-family	No	3	Yes
Tamuning/Tumon	Single-family	Yes	2	Yes
Tamuning/Tumon	Single-family	Yes	2	Yes
Umatac	Single-family	No	2	Yes

Source: FEMA SQANet 2012.

HAZMAT: NPDES-Air Permitted Facilities

Similar to the 2011 HMP, a moderate number of people, 34,147 people (21.43 percent of Guam's population), could be exposed to HAZMAT releases into the atmosphere by a facility with an NPDES permit, as shown in **Tables 5-17 and 5-18**.

This analysis makes the worst-case and, therefore, highly unlikely, assumption that HAZMAT would be released into the atmosphere at the same time from all of the permitted facilities and have catastrophic effects. The best available data for these facilities do not include any characterization of the substances that could be released into the atmosphere. The characteristics of a released gas and the magnitude of a release are unknown and undetermined for these facilities. It is unknown if a release would consist of an Extremely Hazardous Substance or a less harmful HAZMAT that quickly dissipates, like carbon monoxide. Therefore, a worst-case (and highly unlikely) scenario of an atmospheric release that could affect a 1-mile radius around each facility was assumed. For this reason, this vulnerability analysis inherently overemphasizes the hazard.

Similar to previous versions of the plan, Dededo, Tamuning/Tumon, and Yigo have the greatest number of people living in this hazard area. As shown in **Tables F-11 and F-12**, Dededo has the highest exposure with 10,833 people (24.1 percent of the village population), followed by Tamuning/Tumon with 8,460 people (42.98 percent of the village population), and Yigo with 2,756 people (13.42 percent of the village population). All three villages experienced above average population increases from 2000 – 2010.

The portion of EFMUTS and the GBS that could be exposed to a release from these facilities is not included in this discussion. A HAZMAT release into the air would not affect the physical structure or function of these buildings and facilities. The people occupying these buildings and facilities would be affected, but the best available data do not include any information on the number of people (e.g., average number of people, maximum number of people) occupying these buildings and facilities. It is likely that some of these people have been considered because they live in the exposed area. Therefore, it is impractical to accurately determine or estimate the number of people occupying all of the facilities. That being said, the total exposed EFMUTS and GBS and the value of these exposed buildings and facilities are shown in **Tables 5-17 and 5-18** and **Tables F-11 and F-12**.

HAZMAT: NPDES-Water Permitted Facilities

Approximately 15 percent of Guam's population (23,549 people) is directly exposed to HAZMAT releases to surface water from NPDES-permitted facilities, as shown in **Tables 5-17 and 5-18**. The area of exposure of people to HAZMAT releases into surface water from NPDES-permitted facilities was determined to be a 1-mile radius around each facility (regardless of land or water area). In the 2011 Guam HMP, a similar finding of 10 percent of the population was found to be potentially exposed to this hazard.

The quantification of exposed people assumes that releases of catastrophic proportions would occur at all of these NPDES-permitted facilities, which is unlikely. The best available data do not include any characterizations of the substances that could be released other than their release pathway (surface water). The magnitude and toxicity levels of a release are also unknown. The quantified exposure of people reflects a worst-case scenario. Therefore, this vulnerability analysis inherently overemphasizes the hazard.

Detailed analysis by village is shown in **Tables F-13 and F-14**. Similar to the air permitted facilities, the villages with the greatest number of people in water permitted facilities hazard area include Tamuning/Tumon (7,251 people) and Dededo (3,002 people). Both of these villages experienced a greater than average increase in percentage of population from 2000 – 2010.

The portion of EFMUTS and the GBS that could be exposed to a release from these facilities is not included in this discussion. A HAZMAT release into the water would not affect the physical structure or function of these buildings and facilities. The people occupying these buildings and facilities would be affected, but the best available data do not include any information on the number of people (e.g., average number of people, maximum number of people) occupying these buildings and facilities. It is likely that some of these people have been considered because they live in the exposed area. Therefore, it is impractical to accurately determine or estimate the number of people occupying all of the facilities. That being said, the total exposed EFMUTS and GBS and the value of these exposed buildings and facilities are shown in **Tables 5-17 and 5-18** and **Tables F-13 and F-14**.

HAZMAT: Hardfill Sites

A moderate percentage of Guam's population (14.13 percent, or 22,518 people) is directly exposed to an atmospheric release of HAZMAT from all of Guam's hardfill facilities. This percentage is equal to the percentage exposed in the 2011 Guam HMP. This vulnerability analysis assumes a release from all of the known hardfill facilities on Guam, which is an unlikely event. Because of the unknown characteristics and magnitude of the potentially released HAZMAT, this analysis assumes a conservative 1-mile radius around each hardfill site as the potentially affected area. This assumption tends to overemphasize the vulnerability of Guam to this hazard.

At the village level, as shown in **Tables F-15 and F-16**, the population exposed to an atmospheric release of HAZMAT from hardfill facilities is as follows: Yigo has the most people exposed to this hazard (6,350 people, or 30.92 percent of the village population), Mangilao has the second highest number of people exposed (5,454 people, or 35.90 percent of the village population), and Chalan Pago-Ordot has the next highest, with 4,251 people exposed (62.31 percent of the village population). All three villages experienced a significant increase in population change from 2000 – 2010 with Mangilao and Chalan Pago-Ordot increasing in population by 14.1 percent and 15.2 percent, respectively.

The portion of EFMUTS and the GBS that could be exposed to a release from these facilities is not included in this discussion. A HAZMAT release into the atmosphere would not affect the physical structure or function of these buildings and facilities. The people occupying these buildings and facilities would be affected, but the best available data do not include any information on the number of people (e.g., average number of people, maximum number of people) occupying these buildings and facilities. It is likely that some of these people have been considered because they live in the exposed area. Therefore, it is impractical to accurately determine or estimate the number of people occupying all of the facilities. That being said, the total exposed EFMUTS and GBS and the value of these exposed buildings and facilities are shown in **Tables 5-17 and 5-18** and **Tables F-15 and F-16**.

HAZMAT: Pre-CERCLIS Facilities

Similar to results in the 2011 Guam HMP, this 2014 analysis found that a large number of people could be exposed to hazardous release from all of the Pre-CERCLIS facilities. Assuming a 1-mile radius around each Pre-CERCLIS facility as the area of exposure, 118,555 people (74.40 percent of the population of Guam) would be exposed to releases, as shown in **Tables 5-17 and 5-18**.

The exposed EFMUTS include 301 Essential Facilities (worth $852.3 million), 251 Major Utilities (worth $707.2 million), and 124 Transportation Systems (worth $108.5 million).

Similar to earlier versions of the Guam HMP, because of the large number of Pre-CERCLIS facilities (409) on Guam and the general lack of information available for these facilities, the vulnerability analysis of releases from these facilities overemphasizes and exaggerates the hazard. Because of the lack of information, a large area of exposure (i.e., a 1-mile radius around each known facility) was chosen as a conservative and worst-case exposure scenario. The vulnerability analysis examines the exposure resulting from releases at all the sites with a known location (142 facilities) at one time. This scenario is highly unlikely to occur. Therefore, this type of vulnerability analysis, which is the best available analysis that can be conducted with the available resources, overemphasizes the hazard.

Like the earlier versions of the Guam HMP, Dededo has the most exposed people, with 27,149 people (60.41 percent of the village population), as shown in **Tables F-17 and F-18**. Nearly 100 percent of Tamuning/Tumon's 19,685 people (99.98 percent of the village population) are at risk of being exposed to a hazardous release from all of the Pre-CERCLIS facilities. Yigo has the third-highest number of exposed people, with 17,165 people (83.57 percent of the village population).

Based on value of assets, exposure of the Essential Facilities is concentrated in Tamuning/Tumon with 83 facilities that are worth $520.3 million. The greatest concentration of Major Utilities is located in Dededo, with 33 Major Utilities worth $25.4 million. Tamuning/Tumon has 30 Transportation Systems that are exposed, worth $7.9 million. The village with the highest value of Transportation Systems exposed is Piti, with 11 exposed assets worth $75.3 million.

In terms of village-level GBS exposure, Dededo has the most exposure with 4,575 buildings, worth $729.7 million; followed by Yigo with 4,073 buildings, worth $373.7 million.

Severe Wind

As shown in **Tables 5-17 and 5-18** and **Tables F-19 and F-20**, areas exposed to extreme wind contain 84,197 people or 52.8 percent of Guam's population. On a village level, 37,937 people in Dededo (84.41 percent of the village population) and 19,002 people in Yigo (92.52 percent of the village population) are exposed to extreme wind. The third highest village population exposed is Mangilao, with 7,169 exposed people (47.19 percent of the village population). All three villages experienced an above-average change in population growth from 2000 – 2010.

As noted in **Section 5.5.2** (Most Significant Hazards Vulnerability Results), the vulnerability analysis used in this plan includes an assumption that the entire structure value is lost if an EFMUT or GBS is located in the hazard zone. In reality, many buildings and other assets exposed to severe wind may not be completed destroyed; however, this assumption does provide a conservative estimate of potential losses. Also, no contents values, loss of function costs, or displacement/temporary quarters costs are estimated for EFMUTS or GBS. (To address structure and contents damage, more data would be needed related to building age; building condition; construction types; structural connections; roof coverings; window and door type; and window and door protection systems.)

In reality, the functional ability of the commercial and essential facilities to respond after an event is severely affected. Even if it was assumed that the infrastructure was not damaged and could support an operation at these facilities, economic and social impacts will be significant. After recent storms such as Super Typhoon Paka, Typhoon Chata'an, and Super Typhoon Pongsona, businesses and government operations took weeks to months to recover. This loss of function is often the result of lost infrastructure; however, its effects are exacerbated by the inability to prevent wind and water intrusion within commercial and essential buildings.

As mentioned earlier, although a structural failure of these types of buildings is devastating, it is not common to see these types of failures from even these extreme winds. What is more common is measurable structural damage combined with significant, if not total, loss of contents. Although the cost of losing a structure to a typhoon is a real cost, to businesses, governments, and the population, it is what occurs in those buildings that is needed to support the vitality of the social and economic framework of the island.

At the village level, as shown in **Tables F-19 and F-20**, Dededo and Tamuning/Tumon have the highest quantity of Essential Facilities exposed to extreme wind, with 27 and 25 facilities, respectively. Dededo has the highest quantity (80) of Major Utilities worth $119.3 million that are exposed to severe wind. Piti has the highest quantity (9) of Transportation Systems worth $74.8 million exposed.

Additionally, similar to the findings in earlier versions of the Guam HMP, Dededo has the most and highest-valued exposed GBS structures, with 7,339 structures (74.2 percent), worth $117.1

million. Yigo has the second-highest number of exposed structures with the second-highest value, with 4,905 structures (99.9 percent) worth $450.0 million. Mangilao has the third highest value of exposed structures, with 1,502 structures (47.4 percent) worth $222.5 million. The greatest number of building permits were issued in all three villages as follows: 93 permits in Dededo, 64 permits in Yigo, and 46 permits in Mangilao) in 2018.

Slope Failure: Landslide

As shown in **Table 5-17**, 26.5 percent of the landmass on Guam has a very high or high susceptibility to landslides. Similar to previous versions of the plan, approximately 10 percent of the population (16,191) is exposed to this hazard. The number of exposed EFMUTS incudes 31 Essential Facilities worth $17.3 million, 53 Major Utilities (worth $132.6 million), and 23 Transportation Systems (worth $5.1 million). Of the GBS, 1,730 structures (worth $165.8 million) are exposed.

In terms of village-level population were found to be exposed to very high and high landslide hazard, as shown in **Tables F-21 to F-24**, Talofofo and Agat have the largest two vulnerable populations with 2,313 (72.56 percent of the village population) and 2,311 (47.71 percent of the village population) exposed people, respectively. Both Talofofo and Agat experienced a population decrease over from 2000 – 2010 (-5.1 percent and -13.1 percent, respectively), however.

Exposure of the EFMUTS is concentrated in Merizo and Umatac, with 9 Essential Facilities in Merizo that are worth $3.9 million and 9 Essential Facilities in Umatac that are worth $3.1 million. Likewise, 13 Major Utilities are located in the exposed area of Merizo (worth $11.5 million) and 19 Major Utilities are located in the exposed area of Umatac (worth $46.1 million).

Similar to the analyses in earlier versions of the Guam HMP, 100 percent of GBS structures (264 structures) in Umatac are exposed to a very high or high landslide hazard (worth $17.3 million). However, Merizo has the greatest number of exposed GBS, with 613 structures (worth $50.5 million). No new building permits were issued in Merizo during 2018.

Tsunami Inundation

Similar to previous versions of this plan, a relatively low proportion of Guam's population (8,046 people or 5.1 percent) is exposed to tsunami inundation, as shown in **Tables 5-17 and 5-18**. The number of exposed EFMUTS is 93 Essential Facilities (26.2 percent, with a value of $173.3 million), 46 Major Utilities (12.7 percent, with a value of $282.4 million), and 52 Transportation Systems (39.1 percent, with a value of $88.5 million). Of the GBS, 3,270 structures (8.2 percent), worth $555.8 million are exposed.

As noted previously, the lands adjacent to Apra Harbor are likely to be almost completely inundated by a tsunami with a 16-foot run-up. This area includes several port and utility facilities. If permanent damage from a tsunami occurs to port facilities, the movement of goods on and off Guam would also be affected. A value for the normal and daily functions of these facilities has not been assessed for this analysis, but disruption to these functions would be a secondary potential effect of this hazard event. A substantial secondary hazard of a tsunami can occur due to its impact on the functioning of certain utilities, particularly water treatment plants and potable water distribution facilities, which in turn may expose large portions of the population to hazards such as drought and disease.

As shown in **Tables F-25 and F-26**, in terms of village-level population exposed to tsunami hazard, Tamuning/Tumon and Mongmong-Toto-Maite have the largest two vulnerable populations with 2,210 (14.83 percent of the village population) and 1,012 (14.83 percent of the village population) exposed people, respectively. Both villages experienced an above-average change in population growth from 2000 – 2010. In fact, Mongmong-Toto-Maite experienced the greatest change in positive population growth (16.8 percent).

Exposure of the Essential Facilities is concentrated in Hagatna, Tamuning/Tumon, and Piti. Thirty-three Essential Facilities (worth $22.5 million) are located in Hagatna, 19 in Tamuning/Tumon (worth $82.2 million), and 13 in Piti (worth $9.5 million). In terms of Major Utilities, 11 are located in Piti (worth $245.8 million) and 11 in Merizo (worth $6.8 million). In addition, Piti has 11 Transportation Systems in this hazard area that are worth $75.3 million.

The largest number of GBS (568 structures worth $197.5 million) exposed to tsunami inundation are located in Hagatna. Hagatna experienced very little GBS growth in 2018, with only 6 building permits (1.7 percent of all building permits) issued in this village.

Wildland Fire

As noted previously, for the 2014 Guam HMP, a vegetation-based fuel model was used to determine wildland fire hazard areas. This is the same model used in the 2011 Guam HMP which replaced the wildfire model (fuel type, slope, and ladder) used in the 2014 and 2019 Guam HMP.

Similar to the 2011 and 2014 results, a relatively large portion of Guam's population, about 110,000 people (69.1 percent), is exposed to a very high or high wildland fire hazard, as shown in **Tables 5-17 and 5-18**. The EFMUTS exposed include 145 Essential Facilities (worth $360.7 million), 239 Major Utilities (worth $460.7 million), and 73 Transportation Systems (worth $12.1 million). The smallest proportion of exposure is of the GBS, but these structures have the highest combined value, with 21,609 structures exposed, worth $2.87 billion.

In terms of village-level population exposure, as shown in **Tables F-27 and F-28**, Dededo has the largest number of exposed population with 21,309 people residing in a very high wildland fire hazard area (and an additional 15,855 people residing in a high wildland fire hazard area). Yigo has the second highest number of exposed population with 11,074 residing in the very high hazard area and an additional 4,231 people residing in a high wildland fire hazard area. Though Sinajana's overall population is low, Sinajana has the highest proportion of exposure for a village population, with 81.8 percent of the village population of Sinajana very high and high wildland fire hazards.

Exposure of the EFMUTS is concentrated in Tamuning/Tumon with 29 Essential Facilities (worth $202.4 million) located in a very high or high wildland fire hazard area. Dededo has the most Major Utilities located in the very high wildland fire area (31 facilities worth $30.3 million) as well as the high wildland fire area (43 facilities worth $58.3 million). Transportation Systems located in very high or high wildland fire area are located in every village; the village with the highest number is Tamuning/Tumon, with 9 Transportation Systems worth $1.8 million.

Exposure of the GBS to high and very high wildland fire hazards is concentrated in Dededo with 6,089 structures (61.6 percent of the village GBS), worth $971.1 million. As noted previously, the largest number of building permits (93 permits or 25.8 percent of the total permits issued) was issued in Dededo in 2018.

6.1 PURPOSE

The purpose of this section is to present the Government of Guam's hazard mitigation strategy. Specifically, this section describes the processes used to create this strategy, including a capability assessment, a discussion of available mitigation funding sources, a description of mitigation goals, and a comprehensive list of mitigation actions, including an implementation strategy. For the purpose of mitigation planning, goals are defined as general guidelines that explain what a community wants to achieve in terms of hazard and loss prevention. Mitigation actions, also referred to as projects, are specific activities that help a community reach its goals.

The following DMA 2000 requirements for the capability assessment and mitigation strategy do not apply to Guam because the Government of Guam is the only direct grant recipient on Guam.

- Local capability assessment (Requirement § 201.4[c][3][ii])
- Local funding and technical assistance (Requirement § 201.4[c][4][i])
- Local plan integration (Requirement § 201.4[c][4][ii])
- Prioritizing local assistance (Requirement § 201.4[c][4][iii])
- Mitigation actions (Requirement § 201.4[c][3][iii][Element E])

6.2 CAPABILITY ASSESSMENT

The DMA 2000 requirements for consideration by FEMA for the evaluation of the Government of Guam's hazard mitigation capabilities are shown below and addressed in the following text.

DMA 2000 REQUIREMENTS – MITIGATION STRATEGY – STATE CAPABILITY ASSESSMENT
State Capability Assessment Requirement § 201.4(c)(3)(ii): *[The State mitigation strategy* ***shall*** *include a] discussion of the State's pre-and post-disaster hazard management policies, programs, and capabilities to mitigate the hazards in the area, including: an evaluation of State laws, regulations, policies, and programs related to hazard mitigation as well as to development in hazard-prone areas [and] a discussion of State funding capabilities for hazard mitigation projects.*
Element A. Does the new or updated plan include an evaluation of the State's pre-disaster hazard management policies, programs, and capabilities? B. Does the new or updated plan include an evaluation of the State's post-disaster hazard management policies, programs, and capabilities? C. Does the new or updated plan include an evaluation of the State's policies related to development in hazard prone areas? D. Does the new or updated plan include a discussion of State funding capabilities for hazard mitigation projects? E. Does the updated plan address any hazard management capabilities of the State that have changed since approval of the previous plan? Source: FEMA 2008.

6.2.1 Government of Guam Pre- and Post- Disaster Hazard Mitigation Policies and Programs

A detailed list of the Government of Guam's pre- and post-disaster mitigation policies and programs is provided in **Table 6-1**. This table was revised during the 2014 and 2019 Guam HMP update process. **Table 6-1** contains the following information for each policy or program: category, responsible individual and agency (with contact information) for overseeing the policy or program; whether each policy or program is related to pre-disaster or post-disaster hazard mitigation; and whether each policy or program affects development in hazard-prone areas.

The Government of Guam's hazard mitigation funding capabilities are discussed in **Section 6.3** (Funding Sources).

Table 6-1 Pre- and Post-Disaster Mitigation Policies and Programs

Capability Category	Primary Agency Contact Information	Pre/Post Disaster	Effects Development in Hazard-Prone Areas	Description
Management of the GHMGP	Guam GHS/OCD 221B Chalan Palasyo, Agana Heights, Guam 96910	Pre and post	No	The Governor of Guam signed Executive Order 2004-05 in 2004, formally incorporating the GHMGP and the Recovery Coordination Office (RCO) into GHS/OCD. Incorporating the GHMPG within GHS/OCD and empowering the GHMO to manage the GHMPG has provided for continuity and facilitated the selection of effective hazard mitigation projects.
Regulation of Building Construction	DPW 542 North Marine Drive Tamuning/Tumon, Guam 96911	Pre and post	Yes	DPW administers the Building Law and the Building Code, Chapters 66 and 67 of the Guam Code Annotated, Title 21. DPW conducts plan reviews for all building permit requests, ensuring that all buildings conform to the standards described in the Guam Building Code. In September 2010, Guam adopted the 2009 International Building Code/International Residential Code (IBC/IRC) through P.L. 30-199, which mandated that the 2009 IBC/IRC function as the applicable building code for all buildings within Guam and established a Guam Building Code Council. Before passage of this law, Guam used the outdated standards listed in the 1997 Universal Building Code. Adoption of the 2009 IBC/IRC has improved building construction practices within Guam, enabling buildings to better withstand hazards such as tropical cyclones and seismic events.
Regulation of Land Use	DLM 590 South Marine Corps Drive Tamuning/Tumon, Guam 96913	Pre and post	Yes	DLM administers the codes and laws found in Chapters 60 through 63 of the Guam Code Annotated, Title 21. DLM is responsible for managing land use and ensuring consistency of existing and future uses with public goals and interests through management of zoning and subdivisions. The current zoning and subdivision ordinances are limited to regulating type of development allowed (i.e., within zones designated as residential, commercial, or industrial). In addition to the current zoning and subdivision ordinances, Guam should consider adopting hazard-specific overlay zoning ordinances to regulate development in high hazard areas.

Table 6-1 Pre- and Post-Disaster Mitigation Policies and Programs

Capability Category	Primary Agency Contact Information	Pre/Post Disaster	Effects Development in Hazard-Prone Areas	Description
Seashore Reserve Zone	BSP P.O. Box 2950 Hagatna, Guam 96910	Pre and post	Yes	The BSP is in the process of updating the seashore reserve zone ordinance base on technical studies done as a collaborative approach to understand our near shore areas. The update of the seashore reserve zone ordinance is likely to result in the extension of the reserve boundary and changes to land use permitted in the reserve. Extending the seashore reserve and limiting types of development within the seashore reserve zone would create an opportunity to further regulate inappropriate development in hazard-prone areas. The new seashore reserve plan is scheduled to be released in the spring of 2021.
Comprehensive Planning	BSP P.O. Box 2950 Hagatna, Guam 96910	Pre	Yes	The North and Central Guam Land Use Plan is an approved element of the Guam Comprehensive Development Plan. Building resilient communities is a fundamental tenant of the plan. BSP uses is planning authorities to leverage resource in order to create a greater impact.
Comprehensive Planning	BSP P.O. Box 2950 Hagatna, Guam 96910	Pre and post	Yes	GCMP developed an Emergency Response for Impacts on the Environment from Natural Disasters reference guide the purpose of the study is to review the success and failures and level of action in responding to environmental impacts of natural disasters in the past and to develop information and ideas necessary for drafting comprehensive, response plan.

Table 6-1 Pre- and Post-Disaster Mitigation Policies and Programs

Capability Category	Primary Agency Contact Information	Pre/Post Disaster	Effects Development in Hazard-Prone Areas	Description
Floodplain Management / NFIP	DPW 542 North Marine Drive Tamuning/Tumon, Guam 96911	Pre and post	Yes	Guam's floodplain management ordinance was adopted in 1998 in Executive Order 98-30. Guam's floodplain management ordinance guides the management of all floodplain areas, as determined by FEMA maps for flood boundaries and flood insurance. The ordinance enables DPW to oversee management of floodplain areas in a manner that mitigates against tropical cyclone, flood and tsunami events. The floodplain management ordinance meets the minimum requirements of the NFIP, which is discussed below. The NFIP is a voluntary program, whereby a community adopts and enforces ordinances that meet or exceed the minimum floodplain management requirements of the NFIP to reduce future flood damage. In exchange, the NFIP makes federally backed flood insurance available to homeowners, renters, and business owners in these communities. In addition, membership in the NFIP enables Guam to apply for capital-intensive hazard mitigation assistance grants from FEMA hazard mitigation programs, including the PDM, FMA, Severe Repetitive Loss (SRL), and Repetitive Flood Claim (RFC) Programs. Guam became a participating community in the NFIP in November 1985. Guam was placed on probation in April 1992 due to numerous structural and procedural violations. Guam remained on probationary status for 16 years due to numerous structural and procedural NFIP violations. In April 2008, FEMA lifted Guam's probationary status and reinstated Guam into the NFIP.
Economic Impact Analysis	DPW 542 North Marine Drive Tamuning/Tumon, Guam 96911	Pre and post	Yes	Public Law 25-173 requires the government to conduct an economic impact statement of any proposed regulation change estimated to have an economic impact greater than $500,000. Conducting an economic impact statement on proposed regulation changes as part of the decision-making process is a noble concept; however, in practice, this analysis is expensive and time-consuming. The public law does not provide any funding mechanism for conducting this analysis. As a result, this requirement can hinder regulation changes related to hazard mitigation activities.

Table 6-1 Pre- and Post-Disaster Mitigation Policies and Programs

Capability Category	Primary Agency Contact Information	Pre/Post Disaster	Effects Development in Hazard-Prone Areas	Description
Water Resources Management	GWA 578 N. Marine Corps Drive Tamuning/Tumon, Guam 96913	Pre	Yes	GWA published the Guam Water Resources Master Plan in 2007. The master plan contains a comprehensive analysis of wastewater and domestic water systems, improvement alternatives, and needs for the next 20 years. Implementation of the master plan allows GWA to identify critical facilities and vulnerable facilities and mitigate hazards to these assets appropriately, as funding becomes available. The master plan was funded with a combination of an EPA Consolidated Grant (for $1.5 million), GWA CIP funding, and bonds.
Coastal Nonpoint Pollution Management	GEPA 17-3304 Mariner Ave. Tiyan, Guam 96913	Pre and post	No	In 2007, the U.S. EPA and NOAA determined that Guam's Coastal Nonpoint Pollution Control Program met the requirements of the Coastal Zone Act Reauthorization Amendments of 1990. Under the program, GEPA controls nonpoint pollution from agricultural areas, new urban development, existing development, construction sites, roads and bridges, marinas, waterways, and wetlands. The program enables GEPA to support hazard mitigation activities that reduce the potential of nonpoint pollution during floods or tropical cyclones.
Stormwater Management	DPW 542 North Marine Drive Tamuning/Tumon, Guam 96911	Pre	No	The CNMI/Guam Stormwater Management Manual was released in October 2006. In addition, DPW released a Stormwater Drainage Master Plan in 2010. The Master Plan outlines a systematic approach for identify existing stormwater runoff patterns and drainage system and prioritizing drainage improvements, especially in areas of development, for the island of Guam.
Severe Acute Respiratory Syndrome (SARS) Response Management	DPHSS 123 Chalan Kareta, Route 10 Mangilao, Guam 96919	Pre and post	No	DPHSS, in cooperation with other local government agencies, the tourism industry, the medical community, and private industry, has prepared and implemented a SARS Response Manual addressing identification of a SARS case, clinician preparedness to deal with a case of SARS, medical facility preparedness to handle a SARS patient, community preparedness, and public education and awareness. The protocols and procedures that have been developed to respond to a potential SARS case can be applied to a future infectious respiratory disease threat. Agencies, organizations, and individuals that participated in the SARS response manual can be quickly set up as a working task force to respond to other diseases.

Table 6-1 Pre- and Post-Disaster Mitigation Policies and Programs

Capability Category	Primary Agency Contact Information	Pre/Post Disaster	Effects Development in Hazard-Prone Areas	Description
Rodent Control Program	DPHSS 123 Chalan Kareta, Route 10, Mangilao, Guam 96919	Pre	No	Title 10 of the Guam Code, Annotated provides DPHSS with the ability to control plague-infected rodents. DPHSS has established a Vector Control Program to implement and administer the rodent control requirements described in Title 10. The program enables DPHSS to enforce an international quarantine to control rodents, provide the public with rodent bait, and take steps to eradicate rodent harborages and breeding areas.
Drought Management	GWA 578 N. Marine Corps Drive Tamuning/Tumon, Guam 96913	Pre	No	GWA administers the drought management rules and comprehensive water conservation plan described in Title 12 of the Guam Code Annotated, Chapter 14. GWA implements steps for instituting conservation measures and the interruption of water supply, procedures for the protection of water resources pursuant to GWA's statutory role as operator of Guam's sole municipal water and wastewater systems, mandatory restrictions and procedures for control of water use during water shortages, and procedures to alert the community of severity alerts. As part of this program, WERI, in collaboration with USGS's Pacific Water Science Center conducts and administers a Comprehensive Monitoring Program regarding data collection on salt water intrusion, water lens thickness in the northern part of Guam, and stream flow data in the southern part of Guam.
Wildfire Management	Department of Agriculture Forestry & Soils Resources Division 15, Mangilao, Guam	Pre	Yes	Guam Forestry oversees the Guam Forestry Program, which stresses increased planning efforts in all program areas, a step-down approach from an island scale to a watershed and site scale, and a need for increased resources to have the program capacity to carry out strategies as identified in the Guam Statewide Forest and Resource Strategy including: restoration, conservation of intact forests, reduce impacts to water quality and the reef system, mitigate the impacts of the military expansion, and address invasive species.

6.3 FUNDING SOURCES

The DMA 2000 requirements for consideration by FEMA for the hazard mitigation funding sources are shown below and addressed in the following text.

DMA 2000 REQUIREMENTS – MITIGATION STRATEGY – FUNDING SOURCES
Funding Sources
Requirement § 201.4(c)(3)(iv): *[The State mitigation strategy **shall** include an] identification of current and potential sources of Federal, State, local, or private funding to implement mitigation activities.*
Element A. Does the new or updated plan identify current sources of Federal, State, local, or private funding to implement mitigation activities? B. Does the new or updated plan identify potential sources of Federal, State, local, or private funding to implement mitigation activities? C. Does the updated plan identify sources of mitigation funding used to implement activities in the mitigation strategy since approval of the previous plan?
Source: FEMA 2008.

Generally, sources of funding for hazard mitigation activities on Guam can be separated into two categories – Federal sources and Government of Guam sources. As such, private sources are not discussed in this document. Most hazard mitigation activities are funded with federal sources, primarily from FEMA. FEMA grants and most other federal sources are normally supplemented with Government of Guam funds. Sources that Guam is currently using (e.g., sources used during or since Super Typhoon Pongsona in 2002) are discussed in **Section 6.3.1** (Federal Funding Sources for Hazard Mitigation) and **Section 6.3.2** (Government of Guam Funding Sources for Hazard Mitigation). Mitigation funds that have been used to implement the mitigation actions identified in the 2011 and 2014 Guam HMP implementation strategy are discussed in **Section 6.3.3** (Funding Sources Used to Implement Mitigation Actions Identified in the 2014 Guam HMP).

6.3.1 Federal Funding Sources for Hazard Mitigation

The following discussion lists the potential federal funding sources for hazard mitigation activities. The sources are listed by U.S. department or agency and the funding source.

Department of Agriculture

Natural Resources Conservation Service (NRCS) Emergency Watershed Protection Program. For watersheds damaged by severe natural events, this program provides assistance to reduce hazards to life and property. If funds are available, NRCS can provide 100 percent of the cost of exigent situations and 80 percent of the cost of nonexigent situations. Examples of projects funded are construction or improvements of debris basins, installation of debris racks and other barriers, and revegetation. Although typically conducted as response activities, these projects can serve as mitigation against future disaster damage. Under the Emergency Watershed Protection Program, NRCS has authority for the repair of flood control works that is similar to that of the U.S. Army Corps of Engineers (USACE). The NRCS authority applies to drainage basins of 400 square miles or less.

Department of the Army, U.S. Army Corps of Engineers

General Investigation Authority. This program is generally used for large flood damage reduction studies. The first $100,000 is typically federally funded. If the study exceeds this amount, the remaining cost is evenly shared between the USACE and the applicant. Project implementation cost share is 65 percent federal and 35 percent nonfederal match. General Investigation studies require specific congressional authorization.

Continuing Authorities. These programs allow the USACE to take a variety of actions on water resource projects. For these projects, a feasibility study is first performed. Applicant cost shares for these studies vary from 0 to 50 percent. Projects deemed cost-effective and in which a federal interest is established could qualify for up to 75 percent federal funding. Specific Continuing Authorities programs applicable to hazard mitigation include the following:

- Section 204: This program funds dredging associated with authorized navigation projects that protect, restore, and create aquatic or wetland habitats. Study costs include 100 percent federal funding for the initial appraisal and 65 percent federal funding for the feasibility study. The applicant funds up to 35 percent of project costs, including all necessary lands and relocations required for construction. The applicant is responsible for operation and maintenance of the project.
- Section 205: This program funds general small flood control or drainage projects. The first $100,000 of study costs are borne by USACE; additional study costs are shared equally between USACE and the applicant. The applicant incurs between 35 and 50 percent of project costs, including 5 percent in cash. The federal share of project costs is capped at $7 million. The applicant is responsible for operation and maintenance of the project.
- Section 206: This program funds aquatic ecosystem restoration and protection projects, including design, planning, and construction. The federal share for both study costs and project costs is 65 percent, with a maximum of $5 million for project costs. The applicant is responsible for operation and maintenance of the project.
- Section 208: This program funds waterway clearing and snagging. USACE pays the first $40,000 of project costs at 100 percent. Thereafter, the applicant is responsible for 35 percent. The applicant funds between 35 and 50 percent of project costs, including 5 percent in cash. The maximum federal share of project costs is $500,000. The applicant is responsible for operation and maintenance of the project.
- Section 107: This program funds small river and harbor improvement projects. USACE pays study costs in full for the first $100,000; additional study costs are equally shared by the federal government and the applicant. The applicant is responsible for 10 percent of general navigation costs during construction and 10 percent of general navigation costs over a 30-year period. The maximum federal share for project costs is $4 million.
- Section 14: This program funds emergency stream bank and shoreline protection projects. The USACE funds the first $40,000 of study costs at 100 percent and funds 65 percent of additional study costs. The applicant funds up to 35 percent of project costs, including 5 percent in cash. The federal share for project costs is capped at $1 million. The applicant is responsible for operation and maintenance of the project.
- Section 1135: This program is limited to funding environmental restoration projects where a USACE project contributed to the deprivation of the environment. USACE bears 75 percent

of both study costs and project costs, with a maximum contribution of $5 million for project costs. The applicant is responsible for operation and maintenance of the project.

- Section 103. This program funds hurricane and storm damage reduction protection activities. The federal share may not exceed $3 million for each project. Work under this authority provides for protection or restoration of public shorelines by the construction of revetments, groins, and jetties and may include periodic sand replenishment.

Planning Assistance to States. This program assists states in the development of comprehensive plans relating to the development, use, and conservation of water and related land resources. The USACE funds 50 percent of study costs and $25,000 to $75,000 of project costs, with a maximum of $500,000 annual allotment per state/territory. Currently, a waiver exists for initial study costs under this program.

Congressional Authorization (Major Civil Works Projects). Feasibility studies that USACE undertakes for major civil works projects that indicate federal interests (a benefit/cost ratio greater than unity) may be funded through Congressional Authorization of the proposed program.

National Flood Risk Management Program. The National Flood Risk Management Program was established in May 2006 for the purpose of integrating and synchronizing USACE flood risk management programs and activities, both internally and with the counterpart activities of FEMA, other federal agencies, state organizations, and regional and local agencies. This program provides education and planning services for flood hazards and floodplain management.

<u>Department of Commerce, Economic Development Administration</u>

Public Work and Economic Development Facilities Grants. These grants are given to public agencies and private nonprofit organizations for the building or expansion of facilities that are essential to industrial and commercial growth.

Technical Assistance Grants. These grants make funding available to communities and firms for economic feasibility studies of resource development in the establishment of jobs. The funding also provides on-site support for innovative economic development techniques.

Grants to Support Planning Organizations. Funding is available through planning grants to help pay for the expertise needed to plan, coordinate, and implement comprehensive economic development programs.

University Center Economic Development Grants. These grants are awarded to colleges and universities to provide technical assistance and address the economic development problems and opportunities of their service area.

Economic Adjustment Assistance Grants. This program assists states, territories, and local governments in solving recent and anticipated severe adjustment problems that may result in abrupt and serious job losses and helping areas implement strategies to reverse and halt long-term economic deterioration, including natural disasters.

<u>Department of Commerce, National Oceanic and Atmospheric Administration</u>

Coastal Management Program. NOAA enters into partnerships (through cooperative agreements) with states and territories in which NOAA provides funding, technical assistance, and oversight to ensure compliance with the Coastal Zone Management Act. On Guam, the entire island is considered a coastal zone; therefore, the Coastal Management Program on Guam is called the Guam Coastal Management Program. Federal grants are provided on an equal cost-share basis with the state or territory under the following sections of the Coastal Management Program.

- Section 303: This program focuses on the protection of natural resources that mitigate wind and flooding impacts, including beaches, dunes, and barrier islands.
- Section 305: This program provides states and territories with funding to develop their Coastal Zone Management Programs (CZMPs).
- Section 306: This program provides grants for states and territories to administer their CZMPs, including staff salaries, equipment purchases, public education and outreach, enhancement of public access, and the undertaking of projects that monitor and/or enhance elements of the CZMP.
- Section 309: The Coastal Zone Enhancement Program allows states and territories to compete for funding by creating enhancements to the existing state or territory CZMP in eight priority areas, including coastal hazard mitigation, wetlands protection, and the control of cumulative and secondary impacts from development.

Small Business Administration

Physical Disaster Loans and Economic Injury Disaster Loans. The Disaster Division of the Small Business Administration (SBA) provides direct, guaranteed, and insured loans to assist homeowners and businesses suffering economic injury as a result of a disaster declared by the President, the SBA, or the Secretary of Agriculture. Funds under this loan program are not provided merely because of lost income or lost profits; rather, funds may be provided to pay liabilities that the business could have paid if the disaster had not occurred. Working capital can also be provided to allow a business to operate until conditions return to normal. The maximum loan amount is $1.5 million and is based on need. A repayment period of up to 30 years may be granted. The interest rate is not to exceed 4 percent. Over and above the loan amount for the assessed damage, 20 percent in funds may be provided for hazard mitigation activities. Guam has previously used this funding source.

The Concrete Upgrade Policy was instituted in Guam after Super Typhoon Paka in 1997. Pursuant to this policy, when a homeowner or business has more than $10,000 in uncompensated losses for property damage from a declared disaster, the SBA will increase the disaster loan amount to cover the full cost of building a typhoon-resistant concrete or similar structure.

Department of Health and Human Services, Administration for Native Americans (ANA)

Social and Economic Development Strategies (SEDS). The SEDS program provides competitive financial assistance grants to American Indians, Native Americans, Native Alaskans, Native Hawaiians, and Pacific Islanders to promote lasting self-sufficiency and enhance self-government. SEDS promotes self-sufficiency by supporting native communities in their efforts to reduce dependency on public funds and social services by increasing community and individual productivity through community development. Guam currently uses funding from this program.

Environmental Regulatory Enhancement. Environmental quality has a direct impact on the ability of Native American (including Pacific Islander) communities to develop economic and social self-sufficiency. ANA provides grants the Indian Environmental Regulatory Enhancement

Act to assist tribes in the planning, development, and implementation of projects that were designed to improve their capacity to regulate environmental activities.

Department of Health and Human Services, Centers for Disease Control and Prevention

Public Health Emergency Preparedness Cooperative Agreement. This program is administered by the Coordinating Office for Terrorism Preparedness and Emergency. Funds are allocated through cooperative agreements intended to upgrade the preparedness and response capabilities of state and local public health jurisdictions to bioterrorism, outbreaks of infectious disease, and other public health threats and emergencies. To receive funding, state or local public health agencies are required to meet a list of preparedness outcomes, including participation in the Public Health Information Network (which replaced the previous Health Alert Network Program) and development of ERPs and training. The cooperative agreement also lists allowable activities for which funding may be used. States are required to match 5 percent of funding in the first year of a cooperative agreement and 10 percent of funding in the second year and thereafter.

Department of Homeland Security, Federal Emergency Management Agency

Hazard Mitigation Grant Program. The HMGP provides grants to state/territory and local governments to implement long-term hazard mitigation planning and actions after a Presidentially declared disaster. For states and territories with a Standard State Mitigation Plan (Guam has such a plan), HMGP funding for a disaster is valued at 15 percent of the first $2 billion of the total eligible costs associated with FEMA's PA Program and Individual Assistance (IA) Program for that disaster. HMGP funding is valued at 10 percent for the next portion of PA and IA Program costs (between $2 billion and $10 billion). Finally, for PA and IA Program costs of between $10 billion and $35.333 billion, HMGP funds are calculated at 7.5 percent. The federal share of any project will not exceed 75 percent of the total eligible costs of that project. Guam currently uses the HMGP for hazard mitigation funding.

Pre-Disaster Mitigation Program. PDM Program grants are available for planning and mitigation activities implemented before a disaster occurs. The PDM Program provides grants to states/territories and local governments for cost-effective and sustained pre-disaster natural hazard mitigation projects and plans that meet the objectives of the state's or territory's hazard mitigation plan. All PDM applicants, if they have been identified through the NFIP as having a SFHA, must be participating in the NFIP to be eligible for funding.

Public Assistance Program. The PA Program provides supplemental federal disaster grant assistance for the repair, replacement, or restoration of disaster-damaged, publicly owned facilities and the facilities of certain private nonprofit organizations. The federal share is not less than 75 percent of the eligible cost for emergency measures and permanent restoration of these facilities. The PA Program allows for funding to implement cost-effective hazard mitigation measures that restore a facility beyond its pre-disaster condition. PA Program hazard mitigation measures can only be applied to the damaged element of the facility. Further, hazard mitigation measures must be cost-effective (i.e., the hazard mitigation component may amount to no more than 15 percent of the total eligible cost of restoration work on the project, demonstrate a benefit-cost ratio of greater than unity, or meet other conditions). Guam currently uses the PA Program to fund hazard mitigation activities.

Flood Mitigation Assistance Program. The FMA Program provides funding to assist states, territories, and local communities to implement measures to reduce or eliminate the long-term risk of flood damage to buildings, manufactured homes, and other structures insured under the

NFIP. Grants are available for planning, projects, and technical assistance. States and territories are encouraged to prioritize grant applications that include RL properties identified in their Repetitive Loss Strategy and tracked by FEMA in BureauNet and NextGen. Examples of mitigation projects include acquisition, elevation, relocation, flood-proofing, and technical assistance. The enabling legislation specifically excludes large-scale structural flood control projects from receiving this type of funding.

Severe Repetitive Loss Program. The SRL Program provides funding to reduce or eliminate the long-term risk of flood damage to SRL residential structures insured under the NFIP. SRL properties are determined by the number, value, and frequency of NFIP claims. The SRL program funds projects that directly mitigate residential SRL properties. Examples of these projects include elevation, acquisition, relocation, and flood-proofing.

Repetitive Flood Claim Program. The RFC Program provides funding to reduce or eliminate the long-term risk of flood damage to structures insured under the NFIP that have had one or more claim payment for flood damages. RFC funds may only mitigate structures that are within a state or community that cannot meet the cost share or management capacity requirements of the FMA Program. Typical projects include acquisition, elevation, relocation, and flood-proofing.

Homeland Security Grant Program. HSGP is a primary funding mechanism for building and sustaining national preparedness capabilities. HSGP grants enhance the ability of state, local, and tribal governments to prevent, protect against, respond to, and recover from terrorist attacks and other disasters. These grants fund a range of preparedness activities, including planning, organization, equipment purchase, training, exercises, and management and administrative costs. Guam currently uses this funding source.

Buffer Zone Protection Program. The Buffer Zone Protection Program (BZPP) provides grants to build security and risk-management capabilities at the state and local level to secure pre-designated Tier I and Tier II critical infrastructure sites, including chemical facilities, financial institutions, nuclear and electric power plants, dams, stadiums, and other high-risk/high-consequence facilities. The funds provided by BZPP are provided to increase the preparedness capabilities of jurisdictions responsible for the safety and security of communities surrounding high-priority critical infrastructure and key resource assets through allowable planning and equipment acquisition. Guam currently receives BZPP funding.

Port Security Grant Program (PSGP). The PSGP provides grant funding to port areas for the protection of critical port infrastructure from terrorism. PSGP funds help ports enhance their risk management capabilities; domain awareness; training and exercises; and capabilities to prevent, detect, respond to, and recover from attacks involving improvised explosive devices and other nonconventional weapons. Apra Harbor is designated as a Group III port area.

Assistance to Firefighter Grants. Competitive grants are available to provide direct assistance to fire departments for the purpose of protecting the health and safety of the public and fire-fighting personnel against fire and fire-related hazards. Funding to any organization is limited to $750,000 per FY.

Staffing for Adequate Fire and Emergency Response (SAFER) Grants. The SAFER Grant was created to provide funding directly to fire departments and volunteer firefighter interest organizations to help them increase the number of trained, “front-line” firefighters available in their communities. Funding is available for hiring new firefighters to meet Occupational Safety and Health Administration standards. A maximum level of funding of $104,425 per position is provided over a 5-year period. SAFER Grant funding is also available for the recruitment and retention of volunteer firefighters. Funding for volunteer firefighters has no local funding match requirement and no maximum federal share limits.

Department of Housing and Urban Development, Office of Community Planning and Development

Community Development Block Grant Program. The Community Development Block Grant (CDBG) Program is a flexible program that provides communities with resources to address a wide range of unique community development needs. Relevant grant programs include the following:

- **Insular Areas CDBG Program**. HUD annually allocates $7 million of CDBG Program funds to Insular Areas on a formula basis in proportion to the populations of the eligible territories. Funds are provided to territories as a lump sum grant to be distributed by the recipient, within program rules, at the discretion of the territory government. Funding is expected to meet one of the following objectives; providing benefits to low- and moderate-income persons, to assist in the prevention or elimination of slums and blight, and to meet other community development needs having a particular urgency due to health or safety considerations. Typical activities funded include construction of public facilities and improvements, such as water systems, streets, and community centers; rehabilitation of houses and landmark structures; assistance to carry out economic development activities; and the provision of public services. Hazard mitigation activities can be funded as part of CDBGs. Guam currently uses the CDBG Program to fund hazard mitigation activities.
- **Section 108 Loan Guarantee Program**. Section 108 is the loan guarantee provision of the CDBG Program. Through this program, the recipient can transform a small portion of its CDBG funds into federally guaranteed loans large enough to pursue physical and economic revitalization projects. Governments borrowing funds guaranteed by Section 108 must pledge their current and future CDBG allocations to cover the loan amount as security for the loan. Loan commitments are often paired with Economic Development Initiative or Brownfield Economic Development Initiative grants, which can be used to pay predevelopment costs of a Section 108–funded project. They can also be used as a loan loss reserve (in lieu of CDBG funds), to write-down interest rates or to establish a debt service reserve. Section 108 guarantees can be used for projects, including hazard mitigation measures.
- **Disaster Recovery Initiative**. This program provides grants to states and territories to fund gaps in available recovery assistance after disasters. Mitigation activities are eligible as part of the Disaster Recovery Initiative. Guam currently uses this program to fund hazard mitigation activities. This funding is provided on a flexible basis, subject to need and the availability of supplemental appropriations.

Home Investment Partnerships Program. Like the CDBG Program, the Home Investment Partnerships Program provides formula grants to states, territories, and localities to fund a wide range of activities for communities. Home Investment Partnerships Program grants are often provided in partnership with local nonprofit groups. They fund activities relating to building, purchasing, and/or rehabilitating affordable housing for rent or ownership, including hazard mitigation projects. Guam currently uses this funding source.

Emergency Shelter Grants (ESGs). This program provides funding to grantees such as state governments on a formula basis. Funding is available for activities such as conversion, major rehabilitation, or renovation of buildings as emergency shelters and shelter operating expenses. Grantees receive ESG funds and distribute these funds to eligible recipients, which can be either local government agencies or private nonprofit organizations. Grantees, except for state governments, must match ESG funds dollar for dollar with their own locally generated amounts Guam currently receives funding from this program.

Office of Capital Improvements Capital Fund Emergency/Natural Disaster Funding. This program provides grants to public housing agencies for rehabilitation needs resulting from natural disasters or emergency situations. Activities funded under this program include elevation, flood proofing, and seismic retrofits.

Department of the Interior, Office of Insular Affairs

Compact Impact Aid. Compact Impact funding is a special appropriation, allocated by Congress on an annual basis, to provide compensation for and to offset the economic effects of immigration from the Federated States of Micronesia, the Republic of the Marshall Islands, and Palau. The Government of Guam receives $16.8 million annually in Compact Impact Aid.

Disaster Assistance Grants. The Office of Insular Affairs of the U.S. Department of Interior may request up to $2 million annually of Covenant grant funds in the annual budget process for disaster mitigation purposes. The Office of Insular Affairs does not have to identify specific projects or the recipients of this grant funding in the budget process.

Department of the Interior, U.S. Geological Survey

National Earthquake Hazards Reduction Program. The primary objective of National Earthquake Hazards Reduction Program project grants is to mitigate earthquake losses by providing earth science data and assessments essential for warning of imminent damaging earthquakes, land use planning, engineering design, and emergency preparedness decisions. Grants are provided through cooperative agreements and may be provided to colleges and universities, profit-making and nonprofit organizations, and state, territory, or local governments. Grants range in size from $6,000 to $1.1 million, with an average grant size of $56,000. Examples of grants include projects for earthquake loss reduction, earthquake monitoring and forecasting experiments, fault zone studies, and seismic zonation and engineering studies.

Department of Transportation, Federal Highway Administration

Emergency Relief (ER) Program. The ER Program is special component of the Highway Trust Fund for the repair or reconstruction of federal-aid highways and roads on federal lands that have suffered serious damage as a result of (1) natural disasters or (2) catastrophic failures from an external cause. This program supplements the commitment of resources by states or territories to help pay for unusually heavy expenses resulting from extraordinary conditions. The total ER Program obligations for territories is limited to $20 million in any FY. For a large disaster, Congress may pass special legislation lifting the cap for that disaster. Hazard mitigation activities, referred to as “betterments,” may be funded through this program. Guam currently uses this funding source.

Environmental Protection Agency, Office of Water

Wetland Protection Development Grants. These grants are provided to states and territories to support the development and enhancement of wetland protection programs.

Non-Point Source Implementation Grants (319 Program). These grants are provided to states and territories to implement non-point source pollution control programs, including support for non-structural watershed restoration activities.

Clean Water State Revolving Fund. This program provides loans at actual or below-market interest rates to help build, repair, relocate, or replace wastewater treatment plants.

Drinking Water State Revolving Fund. This program provides funds on a formula basis to states for consolidation or maintenance of drinking water supplies, creation of new systems, drinking water storage/treatment and transmission costs, and drinking water security measures.

Water Security Training and Technical Assistance and Water Security Initiative Contamination Warning System Pilots. The objective of these grant programs is to provide financial assistance to improve water infrastructure security through both training and technical assistance for water utilities and cooperative agreements to address the risk of intentional contamination.

6.3.2 Government of Guam Funding Sources for Hazard Mitigation

Similar to most state governments, the Government of Guam establishes a general fund through a cooperative effort between the executive and legislative branches for each FY. Each Government of Guam agency submits a proposed budget to the Guam Bureau of Budget and Management Research (BBMR) annually. BBMR reviews the proposed budget requests, revises the proposals as it determines is necessary, and forwards the proposed budget to the Guam Legislature. The Guam Legislature then drafts a budget for vote, makes revisions as necessary for a consensus, and passes the final budget to the Governor for signature or veto. Unless otherwise stipulated in the law promulgating the budget, each agency determines general fund expenditures based on its authorized budget. Hence, individual agencies have some discretion to determine the percentage of its general fund budget to apply to hazard mitigation activities.

Sources of income for the Government of Guam's general fund include property tax, corporate tax, gross receipt tax, licensing fees, and income tax. The Government of Guam distinguishes between line agencies and autonomous agencies. Line agencies rely completely on the general fund for their budgets; distribution of funds for line agencies occurs through the Department of Administration. Autonomous agencies (such as GPA or the Guam Economic Development Authority [GEDA]) have the potential to create revenue by providing services, goods, or other activities; their funding generally does not pass through the Department of Administration. Government of Guam agencies can also issue bonds to generate revenue. GEDA and the Guam Legislature review proposals for bond flotation.

Individual agencies are responsible for preparing and submitting proposals for federal or other grants; however, BBMR reviews requests for federal grants. Agencies receiving grants that require matching funds are responsible for providing the matching funds as part of their general fund budgets.

By law, the Guam Legislature is authorized to expend up to $250,000 from general fund appropriations for Government of Guam agencies on emergency activities, including those resulting from natural disasters.

6.3.3 Funding Sources Used to Implement Mitigation Actions Identified in the 2014 Guam HMP

As addressed in **Section 7.3.3** (Review of 2014 Implementation Strategy), one mitigation project identified in the 2014 Guam HMP's implementation strategy has been implemented. This pertains to the GMHA Skilled Nursing Unit's (SNU) Typhoon Shutter Project. Funding for this project was provided by the PDM grant.

While not identified in the 2014 Guam HMP, the Government of Guam received HMGP and PDM grants to retrofit Guam Community College Building 200 and Building 300, University of Guam Annex A and B, and Port Authority of Guam Warehouse 1 by installing typhoon shutters or replacing windows and doors. The HMGP and PDM grant is for $3.4 million.

6.4 MITIGATION GOALS

The DMA 2000 requirements for consideration by FEMA for mitigation goals are shown below and addressed in the following text.

DMA 2000 REQUIREMENTS – MITIGATION STRATEGY – HAZARD MITIGATION GOALS
Hazard Mitigation Goals Requirement § 201.4(c)(3)(i): *[The State mitigation strategy **shall** include a] description of State goals to guide the selection of activities to mitigate and reduce potential losses*. Requirement § 201.4(d): *Plan must be reviewed and revised to reflect changes in development, progress in statewide mitigation efforts, and changes in priorities.*
Element A. Does the new or updated plan provide a description of State mitigation goals that guide the selection of mitigation activities? (GOALS are long-term; represent what the state wants to achieve, such as "eliminate flood damage;" and are based on the risk assessment findings.) B. Does the updated plan demonstrate that the goals were assessed and either remain valid or have been revised? Source: FEMA 2008.

Six (6) mitigation goals provide the foundation for the 2019 Guam HMP. Five (5) of these six (6) goals were originally developed for the 2005 Guam HMP through solicitation of the HMAC and through various meetings with Government of Guam agencies and other organizations. Although additional hazards have been added to the Guam HMP in subsequent updates, the GHMO and HMAC determined that the existing mitigation goals continue to address both existing and new hazards. During the 2019 Guam HMP update process, the sixth goal was added.

The goals are as follows.

- Goal 1: Improve the quality and comprehensiveness of information on assets and hazards
- Goal 2: Reduce risks of disaster damage to existing buildings and infrastructure, especially EFMUTS
- Goal 3: Promote disaster-resistant development and disaster recovery
- Goal 4: Develop institutional support of hazard mitigation within Government of Guam agencies and the public
- Goal 5: Protect human health and safety

- Goal 6: Eliminate or reduce the damage to residential property and the disruption of life caused by repeated flooding

6.5 MITIGATION ACTIONS

The DMA 2000 requirements for consideration by FEMA for hazard mitigation actions are shown below and outlined in the following text.

DMA 2000 REQUIREMENTS – MITIGATION STRATEGY – MITIGATION ACTIONS
Mitigation Actions Requirement § 201.4(c)(3)(iii): *[State plans **shall** include an] identification, evaluation, and prioritization of cost-effective, environmentally sound, and technically feasible mitigation actions and activities the State is considering and an explanation of how each activity contributes to the overall mitigation strategy. This section should be linked to local plans, where specific local actions and projects are identified*.
Element A. Does the new or updated plan identify cost-effective, environmentally sound, and technically feasible mitigation actions and activities the State is considering? B. Does the new or updated plan evaluate these actions and activities? C. Does the new or updated plan prioritize these actions and activities? D. Does the new or updated plan explain how each activity contributes to the overall State mitigation strategy? E. Does the new or updated plan address how the mitigation strategy reflects actions and projects identified in local plans? Source: FEMA 2008.

6.5.1 Mitigation Actions

As part of the 2019 Guam HMP update process, the GHMO and HMAC reviewed the remaining 32 mitigation actions selected in the 2014 implementation strategy to determine each mitigation action’s status and relevancy for the 2019 Guam HMP update. **Table 6-2** summarizes the results of this review process.

Out of the 33 mitigation actions identified in the 2014 Guam HMP, four (4) are ongoing and one (1) has been completed. The completed mitigation action is Action No. 11, the GMHA Skilled Nursing Unit (SNU) Typhoon Shutter Project.

In addition to reviewing the existing mitigation actions, the GHMO and HMAC developed 28 new mitigation actions to be included in the list of potential mitigation actions for the 2019 Guam HMP. These mitigation actions are listed in **Table 6-3**.

Resources on Guam needed to address the identified mitigation actions are scarce. Most often, the jurisdiction is reliant on Federal grants to accomplish these mitigation projects. On the other hand, Guam was battered by several of storms since 2015. In fact, Guam has currently four (4) open Presidential declared major disasters. This scarce resources, the competitive nature of the Hazard Mitigation Assistance (HMA) Program, the impact of the major disasters, and the high turn-over of personnel attribute to the slow implementation of Guam’s mitigation strategy.

Table 6-2 2014 Implementation Strategy Review

Action No.	Description	Primary Agency	Estimated Cost	Potential Funding Source**	Estimated Time Frame	Project Status/ Consider for Inclusion in the 2019 Guam HMP
1	Comprehensively inventory and update all EFMUTS at risk from hazards in order to provide emergency responders with accurate information about critical facilities. Inventory information should include exact location, facility type, owner/operator, replacement/insured value, year built, primary structural system, secondary building system/redundancy, building material, roof material/type, mitigation upgrades (e.g., shutters, seismic retrofit), potential secondary impacts due to failure, and prior disaster impacts.	BSP	$200,000	HMGP/PDM	2 years	Not Implemented/ Yes
2	Elevate, retrofit, or otherwise protect bridges and road segments, especially those provide ingress and egress to essential facilities that are susceptible to flooding, landslides, and earthquakes. Fund a study to evaluate vulnerability of these facilities to tsunami events.	DPW	TBD	HMGP/PDM/ FHA/Local Funds	Ongoing	Ongoing/ Yes
3	Develop and implement a process for assessing the hazard vulnerability of school buildings and grounds designated as storm shelters. Upon completion of vulnerability assessment, retrofit buildings and grounds by installing typhoon shutters or replacing windows and doors. This project will mitigate against multiple hazards, including tropical cyclone, severe wind, and disease events.	GDOE	TBD	HMGP/PDM	3 Years	Not Implemented/ Yes
4	Implement applied and emerging vegetation management activities along the interface and intermix hazard areas to mitigate against fire or severe wind events. Examples include creating fuel breaks to separate housing encroachment from brush fields, mechanically constructing fire breaks within brush fields and forests, or trimming foliage posing a threat to power lines or other electrical infrastructure.	DOAg	$400,000	HMGP/PDM/ Local Funds	Ongoing	Ongoing/ Yes

Table 6-2 2014 Implementation Strategy Review

Action No.	Description	Primary Agency	Estimated Cost	Potential Funding Source**	Estimated Time Frame	Project Status/ Consider for Inclusion in the 2019 Guam HMP
5	Upgrade the stormwater drainage system at Harmon Industrial Park in order to resolve documented flooding problems.	GEDA	TBD	HMGP/PDM/ GEDA	TBD	Not Implemented/ Yes
6	Expand/Improve the network of available rain gauges and river gauges in order to enable improved mitigation against erosion. There is a need for 10 additional rain gauges and 5 additional stream gauges. These gauges should have both data-logging and real-time telemetry capability.	BSP	$200,000	HMGP/PDM	1-2 years	Not Implemented/ Yes
7	Install a wave-rider ocean wave buoy in southwestern Guam off-shore waters to mitigate against coastal erosion. The existing ocean wave buoy off Ipan Talofofo cannot detect waves on the west side of Guam, and a similar buoy planned for northwest Guam will not be able to detect the most critical waves affecting the Agat to Merizo area due to blockage by Orote Point.	DOAg	$125,000	HMGP/PDM	6 months	Not Implemented/ Yes
8	Install typhoon shutters and appropriately protected roll-up doors on all emergency services buildings such as fire and police stations not equipped with these features.	GFD; GPD	$500,000	HMGP/PDM	1-2 years	Not Implemented/ Yes
9	Acquire, retrofit, and install back-up power and water systems for all emergency services buildings such as fire and police stations not equipped with these features.	GFD; GPD	TBD	HMGP/PDM	TBD	Not Implemented/ Yes

Table 6-2 2014 Implementation Strategy Review

Action No.	Description	Primary Agency	Estimated Cost	Potential Funding Source**	Estimated Time Frame	Project Status/ Consider for Inclusion in the 2019 Guam HMP
10	Remove the large storefront windows located at the Front & Middle Courtyard Areas of the Guam Memorial Hospital (located in Tamuning/Tumon, Guam) along the 1st and 2nd floor main corridors in order to limit water seepage during heavy rains and tropical cyclones that cause slippery, unsafe conditions in the 1st and 2nd floor main corridors. The project scope will also include installation of smaller windows; upgraded aluminum, accordion-type typhoon shutters; plaster and metal stud type wall restoration; lowering affected corridor ceiling systems; replacing affected flooring systems; and electrical and mechanical appurtenances.	GMHA	$700,000	HMGP/PDM	12-18 months	Not Implemented/ Yes
11	Install automated, internally controlled typhoon shutters at the Guam Memorial Hospital Authority's Skilled Nursing Unit (located in Barrigada, Guam) in order to mitigate against severe wind and rain hazards from tropical cyclones.	GMHA	$400,000	PDM	6 months – 1 year	Completed/ No
12	Ensure that within GHS/OCD, the GHMO position is a fulltime position and the Guam HMP is reviewed and updated by the GHMO and HMAC and adopted by the Governor every 5 years.	GHS/OCD	TBD	HMGP/PDM	Ongoing	Ongoing/ Yes
13	For Mayor's Offices located outside of the SFHA, retrofit and harden all existing Mayor's Offices with Typhoon Shutters and Emergency Generators. For Mayor's Offices located within the SFHA, relocate offices to higher ground and retrofit and harden relocated structures with Typhoon Shutters and Emergency Generators.	MCOG	TBD	HMGP/PDM	Retrofit – 1 year, Relocation – 3 years	Not Implemented/ Yes

Table 6-2 2014 Implementation Strategy Review

Action No.	Description	Primary Agency	Estimated Cost	Potential Funding Source**	Estimated Time Frame	Project Status/ Consider for Inclusion in the 2019 Guam HMP
14	Update Guam's Threat and Hazard Identification and Risk Assessment (THIRA) following guidance issued in the second edition of the Comprehensive Preparedness Guide 201. Consider integrating Desired Outcomes into the existing Guam Comprehensive Emergency Management Plan. In addition, through the THIRA process, identify opportunities to employ mitigation projects to reduce the loss of life and damage to property thereby reducing the impacts needed to manage, and hence reduce the resources needed to achieve capability targets.	GHS/OCD	TBD	State Homeland Security Program	3 years	Ongoing/ Yes
15	Harden captive holding and breeding cages of Endangered Guam rail and Guam Micronesian kingfishers to continue efforts and its noninterruption before, during and after a typhoon or earthquake.	DOAg	TBD	HMGP	2-years	Not Implemented/ Yes
16	Weatherize operating controls, pumps and generators for the potable water and wastewater facilities (e.g., upgrade electrical equipment to include storm rate electrical cabinets) for the Captive breeding facility at DAWR/Agriculture Protect all such facilities located within tsunami inundation zones.	DOAg	TBD	HMGP	TBD	Not Implemented/ Yes
17	Harden the Plant Inspection Facility and Plant Nursery and Tissue Culture Facility with typhoon shutters for doors and windows and weatherize the roof.	DOAg	TBD	HMGP/PDM	TBD	Not Implemented/ Yes
18	Harden of current endangered and threatened bird cage facilities against tropical cyclones. Remove and replace current wooden cages with concrete structure and typhoon shutters which will provide shelter and safe haven for the endangered birds.	DOAg	TBD	HMGP/PDM	TBD	Not Implemented/ Yes

Table 6-2 2014 Implementation Strategy Review

Action No.	Description	Primary Agency	Estimated Cost	Potential Funding Source**	Estimated Time Frame	Project Status/ Consider for Inclusion in the 2019 Guam HMP
19	Strengthen Law Enforcement Boat House and Storage Annex to withstand typhoon/earthquake.	DOAg	TBD	HMGP/PDM	TBD	Not Implemented/ Yes
20	Design and build a rooftop, gravity flow type emergency water supply system (to include 4 rooftop water tanks approx. 5,000 gallons each) to be located on rooftop areas of the Guam Memorial Hospital. As the Guam Memorial Hospital is a critical infrastructure, this emergency water supply is needed to sustain GMHA's operations for a period of 4 to 5 days when tropical cyclones cause a temporary GWA water outage or disruption that may negatively impact GMHA.	GMHA	$400,000	HMGP/PDM	12-18 months	Not Implemented/ Yes
21	Design and install to elevate electrical controls for flood management purposes of all existing internal and external electrical equipment at the SPS including but not limited to the motor control center, generator or housing construction, battery charger, day tank, bubbler level control system, transformer, and junction box and any and all other equipment and appurtenances.	GWA	$6,300,000	TBD	TBD	Not Implemented/ Yes
22	Design and install new weather proof components and to elevate electrical controls for flood management purposes of all existing internal and external electrical equipment at the SPS and deepwells including but not limited to the motor control center, chlorination housing, generator or housing construction, battery charger, day tank, bubbler level control system, transformer, and junction box and any and all other equipment and appurtenances.	GWA	$10,800,000	TBD	TBD	Not Implemented/ Yes

Table 6-2 2014 Implementation Strategy Review

Action No.	Description	Primary Agency	Estimated Cost	Potential Funding Source**	Estimated Time Frame	Project Status/ Consider for Inclusion in the 2019 Guam HMP
23	Weatherize and harden the GWA warehouse and facilities maintenance buildings from high winds, earthquakes and heavy rain.	GWA	$5,000,000	TBD	TBD	Not Implemented/ Yes
24	Convert all non-concrete water tank/reservoirs to concrete in order to mitigate against multiple hazards, including flood events and tropical cyclones. GWA has a total of thirty-eight tanks for this project with various capacity, totaling 37.8 million gallons of capacity.	GWA	$124,000,000	TBD	TBD	Not Implemented/ Yes
25	Install Power Conditioner Voltage Regulator at all deep wells and sewer pump stations to eliminate substandard electricity brought on during and after heavy winds and rains that cause frequent brownouts and power fluctuations.	GWA	$18,000,000	TBD	TBD	Not Implemented/ Yes
26	Provide concrete roofing for 5 air handling units which service the public health facility in Mangilao in order to mitigate against tropical cyclones or other disasters.	DPHSS	$80,000	HMGP/PDM	6 months – 1 year	Not Implemented/ Yes
27	Retrofit seven (7) double doors at the public health facility in Mangilao with panel/accordion shutters to withstand typhoon strength winds.	DPHSS	$25,000	HMGP/PDM	3-6 months	Not Implemented/ Yes
28	Acquire, retrofit and install back-up power and water systems for all department service buildings such as our Youth Correctional Facility, Cottage Homes Facility, and the three resource centers in Agat, Mangilao, and Dededo centers.	DYA	TBD	HMGP/PDM	TBD	Not Implemented/ Yes

Table 6-2 2014 Implementation Strategy Review

Action No.	Description	Primary Agency	Estimated Cost	Potential Funding Source**	Estimated Time Frame	Project Status/ Consider for Inclusion in the 2019 Guam HMP
29	Repair and upgrade the anchor blocks, chains, and moorings systems at all 52 moorings in the PAG's Harbor of Refuge.	PAG	$500,000	HMGP/PDM/ Port Modernization Funds	2 years	Not Implemented/ Yes
30	Increase Height of Concrete Wall Along the Shoreline of Route 11 to increase of the existing wall to a design wave height of 8.1 feet and prevent future flooding.	PAG	$2,000,000	HMGP/PDM/ Port Modernization Funds	2 years	Not Implemented/ Yes
31	Replace and/or refurbish all generator load centers and harden PAG buildings and facilities with new windows, typhoon shutters and coiling doors, to conform to wind speed requirements found in the 2012 International Building Code.	PAG	$750,000	HMGP/PDM/ Port Modernization Funds	2 years	Ongoing/ Yes
32	Harden one wooden office (structure) at the DPHSS central facility in Mangilao from class D (wooden) to class A (concrete).	DPHSS	$150,000	HMGP/PDM	1-2 years	Not Implemented/ Yes
33	Develop a RL property strategy to verify loss information, collect information about flood risks, and implement a mitigation program mitigate these properties. Mitigation efforts may include: retrofitting, elevating, and floodproofing structures.	DPW	TBD	TBD	1-2 years	Not Implemented/ Yes

Table 6-3 Newly Developed Mitigation Actions for the 2019 Guam HMP

Action No.	Description	Primary Agency	Estimated Cost	Potential Funding Source**	Estimated Time Frame
1	Scope, gain NEPA approval, and develop final design for the most cost effective solution to restore Agueda River flow beneath Route 1, and mitigate flooding of Route 1 near the intersection of Polaris Point Road. This work would also include ROW acquisition as needed, and any required environmental permitting. This project is included in DPW's 2010 Storm Water Drainage Master Plan and is indicated as a high priority regional project that would benefit both the villages of Piti, Asan, Santa Rita, and Agat. The NAVY, GHS/OCD, GFD and GPD have indicated that the project is extremely critical due to the severity of the flooding of Route 1, which restricts emergency responder access during storm events.	DPW	$3,600,000	HMGP/PDM/ GovGuam Funds	3 years
2	Retrofit Building 500 to harden Butler-tin structure by replacing with concrete envelope and to mitigate against storm strength wind events, to bring building up to electrical code, and to reduce loss of life, damage to surrounding buildings on campus from storms and typhoons, and to prevent disruption of educational training and services.	GCC	$4,000,000	HMGP/PDM/ Guam Community College Foundation	1-2 years
3	Retrofit Building 600 to harden Butler-tin structure by replacing with concrete envelope and to mitigate against storm strength wind events, to bring building up to electrical code, and to reduce loss of life, damage to surrounding buildings on campus from storms and typhoons, and to prevent disruption of educational training and services.	GCC	$4,000,000	HMGP/PDM/ Guam Community College Foundation	1-2 years
4	Retrofit Building 900 to harden Butler-tin structure by replacing with concrete envelope and to mitigate against storm strength wind events, to bring building up to electrical code, and to reduce loss of life, damage to surrounding buildings on campus from storms and typhoons, and to prevent disruption of educational training and services.	GCC	$4,000,000	HMGP/PDM/ Guam Community College Foundation	1-2 years

Table 6-3 Newly Developed Mitigation Actions for the 2019 Guam HMP

Action No.	Description	Primary Agency	Estimated Cost	Potential Funding Source**	Estimated Time Frame
5	Mitigate the damages to GHC's rental units by providing typhoon shutters to all units within GHC's purview (i.e. Lada Estates, Sagan Linahyan and Guma As-Atdas).	GHC	TBD	HMGP/PDM/ GovGuam Funds	TBD
6	Mitigate flooding issues at Lada Estates, Dededo, due to the ponding basin being closed off to Lada Estates.	GHC, GEPA, DPW, GWA	TBD	HMGP/PDM/ GovGuam Funds	TBD
7	Convert existing overhead distribution primary and secondary power lines to an underground electrical system composed of manholes, handholes, conduits, underground power cables, splices, and accessories to eliminate typhoon hazard.	GPA	TBD	HMGP/PDM/ Revenue	30 years
8	Clara St. Underground Conversion (Mongmong) Distribution primary and secondary power lines overhead to underground conversion in a system of manholes, handholes, and underground power cables and accessories.	GPA	$250,000	HMGP/PDM/ Revenue	1 year
9	Convert existing overhead transmission power lines to an underground electrical system composed of manholes, handholes, conduits, underground power cables, splices, and accessories to eliminate typhoon hazard.	GPA	TBD	HMGP/PDM/ Revenue	30 years
10	Tumon Bay Lateral Conversion Distribution primary and secondary power lines overhead to underground conversion in a system of manholes, handholes, and underground power cables and accessories.	GPA	$7,280,000	HMGP/PDM/ Revenue	2 years
11	Hardening of overhead primary lines to replace existing wood poles with concrete poles and conversion of overhead secondary to underground electrical system of conduits, handholes, underground cables and accessories.	GPA	TBD	HMGP/PDM/ Revenue	30 years
12	Kaiser Hybrid Conversion (Chichirica, Sta Barbara, Amates) Hardening of overhead primary lines to replace existing wood poles with concrete poles and conversion of overhead secondary to underground electrical system of conduits, handholes, underground cables and accessories.	GPA	$2,600,000	HMGP/PDM/ Revenue	2 years

Table 6-3 Newly Developed Mitigation Actions for the 2019 Guam HMP

Action No.	Description	Primary Agency	Estimated Cost	Potential Funding Source**	Estimated Time Frame
13	Design and install backup generators for critical deepwells, booster pump stations, and sewer treatment plants including but not limited to generators, fuel storage systems, monitoring equipment, hardened building, automatic transfer switches, and other electrical equipment and appurtenances. This is to ensure constant water and wastewater services for island residents in the event of natural disasters.	GPA	TBD	HMGP/PDM/ Revenue	5 years
14	Kaiser Hybrid Conversion (San Antonio Avenue) Hardening of overhead primary lines to replace existing wood poles with concrete poles and conversion of overhead secondary to underground electrical system of conduits, handholes, underground cables and accessories.	GPA	$1,000,000	HMGP/PDM/ Revenue	2 years
15	Design and install backup generators for critical facilities such as school/housing shelters including but not limited to generators, fuel storage systems, monitoring equipment, hardened building, automatic transfer switches, and other electrical equipment and appurtenances.	GPA	TBD	HMGP/PDM/ Revenue	10 years
16	Liguan Terrace Hybrid Conversion - Phase I Hardening of overhead primary lines to replace existing wood poles with concrete poles and conversion of overhead secondary to underground electrical system of conduits, handholes, underground cables and accessories.	GPA	$2,000,000	HMGP/PDM/ Revenue	3 years
17	Liguan Terrace Hybrid Conversion - Phase II Hardening of overhead primary lines to replace existing wood poles with concrete poles and conversion of overhead secondary to underground electrical system of conduits, handholes, underground cables and accessories.	GPA	$2,000,000	HMGP/PDM/ Revenue	3 years
18	Barrigada Village - Phase I Hardening of overhead primary lines to replace existing wood poles with concrete poles and conversion of overhead secondary to underground electrical system of conduits, handholes, underground cables and accessories.	GPA	$4,000,000	HMGP/PDM/ Revenue	4 years
19	Agana Heights - Phase I Hardening of overhead primary lines to replace existing wood poles with concrete poles and conversion of overhead secondary to underground electrical system of conduits, handholes, underground cables and accessories.	GPA	$4,000,000	HMGP/PDM/ Revenue	5 years

Table 6-3 Newly Developed Mitigation Actions for the 2019 Guam HMP

Action No.	Description	Primary Agency	Estimated Cost	Potential Funding Source**	Estimated Time Frame
20	Yigo Village - Phase I Hardening of overhead primary lines to replace existing wood poles with concrete poles and conversion of overhead secondary to underground electrical system of conduits, handholes, underground cables and accessories.	GPA	$4,000,000	HMGP/PDM/ Revenue	5 years
21	Agana Village - Phase I Hardening of overhead primary lines to replace existing wood poles with concrete poles and conversion of overhead secondary to underground electrical system of conduits, handholes, underground cables and accessories.	GPA	$4,000,000	HMGP/PDM/ Revenue	5 years
22	Tamuning Village - Phase I Hardening of overhead primary lines to replace existing wood poles with concrete poles and conversion of overhead secondary to underground electrical system of conduits, handholes, underground cables and accessories.	GPA	$4,000,000	HMGP/PDM/ Revenue	5 years
23	Harden PAG buildings and facilities with new windows, typhoon shutters and coiling doors, to conform to wind speed requirements found in the 2012 International Building Code.	PAG	$750,000	HMGP/PDM	2 years
24	Weatherize and harden dormitory buildings as follows Dormitory I - Building Number 637, Dormitory II - Building number 657, and Dormitory III - Building Number 679: (1) To protect life and interior contents from future damages caused by typhoons, (2) To reduce man-hours required to secure unsecured buildings, and (3) To eliminate cost of purchasing plywood, related materials such as fasteners and lift rental currently used to secure unprotected dormitory buildings. In the case of a most recent Typhoon Mangkhut, it cost $36,781 with an estimate damage cost of $63,736. Alternative is to continue to secure windows and doors with plywood. The Dormitories is 46,826 square feet for all three (3) buildings and has a maximum capacity of 220 residences. They were designed as an enclosed building back in 1970 and the building structure (including all doors) was originally designed and constructed to withstand a 110 miles per hour wind. The shutter system will be designed to withstand positive and negative wind pressures associated with devastating Category 5 wind speeds.	UOG	• Dormitory I, Building number 637 approximate cost of $110,000 • Dormitory II, Building number 657 approximate cost is $135,000 • Dormitory III, Building number 679 approximate cost is $98,000	HMGP/PDM	1 year

Table 6-3 Newly Developed Mitigation Actions for the 2019 Guam HMP

Action No.	Description	Primary Agency	Estimated Cost	Potential Funding Source**	Estimated Time Frame
25	Execute the Agana River Flood Control Project with the USACE. The project was original authorized under the WRDA of 1986 but was admiratively de-authorized in April 2002. A General Reevaluation Request is being considered by USACE.	DPW, BSP	$10,000,000	USACE, USDOT, DPW	4 years
26	Develop a proposal to initiate flood and erosion mitigation option as proposed by USACE under Section 205 Flood Damage Reduction of the Continuing Authorities Program for Manell River, Umatac River, and Namo River.	DPW, BSP	$10,000,000	USACE, USDOT, DOI, DOC	4 years
27	Implement mitigation actions indicated in the Agat Bay Regional Shoreline Assessment	PAG, DPR	$10,000,000	PAG, DOC USACE, DOI DOC, GPA	4 years
28	Implement adaptive management interventions based on the best available science and reduce local pressures and increase coral reef resilience to climate change as described in the 2018 Coral Reef Resilience Strategy	DOAg	$5,000,000	DOAg, CRI, CRCP, DOI BSP	4 years

*TBD = To be determined, ** HMGP = FEMA's Hazard Mitigation Grant Program, PDM = FEMA's Pre-Disaster Mitigation Grant Program

6.5.2 Evaluation and Prioritization of Mitigation Actions

The GHMO, GHS/OCD Mitigation staff, and consultant worked together to merge **Tables 6-2 and 6-3** into one list of mitigation actions to be considered for the 2014 Guam HMP implementation strategy.

The HMAC followed the prioritization criteria developed for the 2011 and 2014 Guam HMP's implementation strategy to determine "high priority" mitigation actions. The HMAC voted for mitigation actions to be included in the 2019 Guam HMP's implementation strategy using the following criteria:

1. Mitigates the most significant hazards and/or multiple hazards
2. Has ability to reduce expected future damages and losses (cost-benefit)
3. Has political and/or public support
4. Has a funding mechanism available
5. Has ability to be implemented over the next 3 years to 5 years

Table 6-4 lists 15 "high-priority" mitigation actions that were selected by the HMAC. **Table 6-4** includes 17 additional "high priority" mitigation actions selected by the GHMO after additional input from the stakeholders, specific Government of Guam agencies and FEMA. Mitigation actions not selected by the HMAC or GHMO are considered "low priority" mitigation actions. These mitigation actions are still included in the 2019 Guam HMP implementation strategy as priorities and funding availability can change the ranking order of mitigation actions listed in the implementation strategy.

Over the next five years, the GHMO and GHS/OCD Mitigation staff will work with various members of the HMAC and the Government of Guam to fund and implement the 32 "high priority" mitigation actions, thereby contributing to the overall State mitigation strategy (see **Section 6.5.3** [Contribution to the Overall State Mitigation Strategy]).

Table 6-4 identifies these 60 mitigation actions and includes the following information for each mitigation action: primary department or agency responsible; estimated cost; potential funding source; and estimated time frame for implementation.

Table 6-4 Implementation Strategy

Action No.	Description	Primary Agency	Estimated Cost	Potential Funding Source**	Estimated Time Frame	Priority
1	Comprehensively inventory and update all EFMUTS at risk from hazards in order to provide emergency responders with accurate information about critical facilities. Inventory information should include exact location, facility type, owner/operator, replacement/insured value, year built, primary structural system, secondary building system/redundancy, building material, roof material/type, mitigation upgrades (e.g., shutters, seismic retrofit), potential secondary impacts due to failure, and prior disaster impacts.	BSP	$200,000	HMGP/PDM	2 years	High
2	Elevate, retrofit, or otherwise protect bridges and road segments, especially those provide ingress and egress to essential facilities that are susceptible to flooding, landslides, and earthquakes. Fund a study to evaluate vulnerability of these facilities to tsunami events.	DPW	TBD	HMGP/PDM	Ongoing	High
3	Develop and implement a process for assessing the hazard vulnerability of school buildings and grounds designated as storm shelters. Upon completion of vulnerability assessment, retrofit buildings and grounds by installing typhoon shutters or replacing windows and doors. This project will mitigate against multiple hazards, including tropical cyclone, severe wind, and disease events.	GDOE	TBD	HMGP/PDM	3 Years	High
4	Implement applied and emerging vegetation management activities along the interface and intermix hazard areas to mitigate against fire or severe wind events. Examples include creating fuel breaks to separate housing encroachment from brush fields, mechanically constructing fire breaks within brush fields and forests, or trimming foliage posing a threat to power lines or other electrical infrastructure.	DOAg	$400,000	HMGP/PDM	Ongoing	High
5	Upgrade the stormwater drainage system at Harmon Industrial Park in order to resolve documented flooding problems.	GEDA	TBD	HMGP/PDM/ GEDA	TBD	Low

Table 6-4 Implementation Strategy

Action No.	Description	Primary Agency	Estimated Cost	Potential Funding Source**	Estimated Time Frame	Priority
6	Expand/Improve the network of available rain gauges and river gauges in order to enable improved mitigation against erosion. There is a need for 10 additional rain gauges and 5 additional stream gauges. These gauges should have both data-logging and real-time telemetry capability.	BSP	$200,000	HMGP/PDM	1-2 years	Low
7	Install a wave-rider ocean wave buoy in southwestern Guam off-shore waters to mitigate against coastal erosion. The existing ocean wave buoy off Ipan Talofofo cannot detect waves on the west side of Guam, and a similar buoy planned for northwest Guam will not be able to detect the most critical waves affecting the Agat to Merizo area due to blockage by Orote Point.	DOAg	$125,000	HMGP/PDM	6 months	Low
8	Install typhoon shutters and appropriately protected roll-up doors on all emergency services buildings such as fire and police stations not equipped with these features.	GFD; GPD	$500,000	HMGP/PDM	1-2 years	High
9	Acquire, retrofit, and install back-up power and water systems for all emergency services buildings such as fire and police stations not equipped with these features.	GFD; GPD	TBD	HMGP/PDM	TBD	High
10	Remove the large storefront windows located at the Front & Middle Courtyard Areas of the Guam Memorial Hospital (located in Tamuning/Tumon, Guam) along the 1st and 2nd floor main corridors in order to limit water seepage during heavy rains and tropical cyclones that cause slippery, unsafe conditions in the 1st and 2nd floor main corridors. The project scope will also include installation of smaller windows; upgraded aluminum, accordion-type typhoon shutters; plaster and metal stud type wall restoration; lowering affected corridor ceiling systems; replacing affected flooring systems; and electrical and mechanical appurtenances.	GMHA	$700,000	HMGP/PDM	12-18 months	High
11	Ensure that within GHS/OCD, the GHMO position is a fulltime position and the Guam HMP is reviewed and updated by the GHMO and HMAC and adopted by the Governor every 5 years.	GHS/OCD	TBD	HMGP/PDM	Ongoing	High

Table 6-4 Implementation Strategy

Action No.	Description	Primary Agency	Estimated Cost	Potential Funding Source**	Estimated Time Frame	Priority
12	For Mayor's Offices located outside of the SFHA, retrofit and harden all existing Mayor's Offices with Typhoon Shutters and Emergency Generators. For Mayor's Offices located within the SFHA, relocate offices to higher ground and retrofit and harden relocated structures with Typhoon Shutters and Emergency Generators.	MCOG	TBD	HMGP/PDM	Retrofit – 1 year, Relocation – 3 years	High
13	Update Guam's Threat and Hazard Identification and Risk Assessment (THIRA) following guidance issued in the second edition of the Comprehensive Preparedness Guide 201. Consider integrating Desired Outcomes into the existing Guam Comprehensive Emergency Management Plan. In addition, through the THIRA process, identify opportunities to employ mitigation projects to reduce the loss of life and damage to property thereby reducing the impacts needed to manage, and hence reduce the resources needed to achieve capability targets.	GHS/OCD	TBD	State Homeland Security Program	3 years	High
14	Harden captive holding and breeding cages of Endangered Guam rail and Guam Micronesian kingfishers to continue efforts and its noninterruption before, during and after a typhoon or earthquake.	DOAg	TBD	HMGP	2-years	Low
15	Weatherize operating controls, pumps and generators for the potable water and wastewater facilities (e.g., upgrade electrical equipment to include storm rate electrical cabinets) for the Captive breeding facility at DAWR/Agriculture Protect all such facilities located within tsunami inundation zones.	DOAg	TBD	HMGP	TBD	Low
16	Harden the Plant Inspection Facility and Plant Nursery and Tissue Culture Facility with typhoon shutters for doors and windows and weatherize the roof.	DOAg	TBD	HMGP/PDM	TBD	High
17	Harden of current endangered and threatened bird cage facilities against tropical cyclones. Remove and replace current wooden cages with concrete structure and typhoon shutters which will provide shelter and safe haven for the endangered birds.	DOAg	TBD	HMGP/PDM	TBD	Low

Table 6-4 Implementation Strategy

Action No.	Description	Primary Agency	Estimated Cost	Potential Funding Source**	Estimated Time Frame	Priority
18	Strengthen Law Enforcement Boat House and Storage Annex to withstand typhoon/earthquake.	DOAg	TBD	HMGP/PDM	TBD	Low
19	Design and build a rooftop, gravity flow type emergency water supply system (to include 4 rooftop water tanks approx. 5,000 gallons each) to be located on rooftop areas of the Guam Memorial Hospital. As the Guam Memorial Hospital is a critical infrastructure, this emergency water supply is needed to sustain GMHA's operations for a period of 4 to 5 days when tropical cyclones cause a temporary GWA water outage or disruption that may negatively impact GMHA.	GMHA	$400,000	HMGP/PDM	12-18 months	High
20	Design and install to elevate electrical controls for flood management purposes of all existing internal and external electrical equipment at the SPS including but not limited to the motor control center, generator or housing construction, battery charger, day tank, bubbler level control system, transformer, and junction box and any and all other equipment and appurtenances.	GWA	$6,300,000	TBD	TBD	Low
21	Design and install new weather proof components and to elevate electrical controls for flood management purposes of all existing internal and external electrical equipment at the SPS and deepwells including but not limited to the motor control center, chlorination housing, generator or housing construction, battery charger, day tank, bubbler level control system, transformer, and junction box and any and all other equipment and appurtenances.	GWA	$10,800,000	TBD	TBD	Low
22	Weatherize and harden the GWA warehouse and facilities maintenance buildings from high winds, earthquakes and heavy rain.	GWA	$5,000,000	TBD	TBD	Low

Table 6-4 Implementation Strategy

Action No.	Description	Primary Agency	Estimated Cost	Potential Funding Source**	Estimated Time Frame	Priority
23	Convert all non-concrete water tank/reservoirs to concrete in order to mitigate against multiple hazards, including flood events and tropical cyclones. GWA has a total of thirty-eight tanks for this project with various capacity, totaling 37.8 million gallons of capacity.	GWA	$124,000,000	TBD	TBD	Low
24	Install Power Conditioner Voltage Regulator at all deep wells and sewer pump stations to eliminate substandard electricity brought on during and after heavy winds and rains that cause frequent brownouts and power fluctuations.	GWA	$18,000,000	TBD	TBD	Low
25	Provide concrete roofing for 5 air handling units which service the public health facility in Mangilao in order to mitigate against tropical cyclones or other disasters.	DPHSS	$80,000	HMGP/PDM	6 months – 1 year	Low
26	Retrofit seven (7) double doors at the public health facility in Mangilao with panel/accordion shutters to withstand typhoon strength winds.	DPHSS	$25,000	HMGP/PDM	3-6 months	Low
27	Acquire, retrofit and install back-up power and water systems for all department service buildings such as our Youth Correctional Facility, Cottage Homes Facility, and the three resource centers in Agat, Mangilao, and Dededo centers.	DYA	TBD	HMGP/PDM	TBD	Low
28	Repair and upgrade the anchor blocks, chains, and moorings systems at all 52 moorings in the PAG's Harbor of Refuge.	PAG	$500,000	HMGP/PDM/ Port Modernization Funds	2 years	High
29	Increase Height of Concrete Wall Along the Shoreline of Route 11 to increase of the existing wall to a design wave height of 8.1 feet and prevent future flooding.	PAG	$2,000,000	HMGP/PDM/ Port Modernization Funds	2 years	Low

Table 6-4 Implementation Strategy

Action No.	Description	Primary Agency	Estimated Cost	Potential Funding Source**	Estimated Time Frame	Priority
30	Replace and/or refurbish all generator load centers and harden PAG buildings and facilities with new windows, typhoon shutters and coiling doors, to conform to wind speed requirements found in the 2012 International Building Code.	PAG	$750,000	HMGP/PDM/ Port Modernization Funds	2 years	Low
31	Harden one wooden office (structure) at the DPHSS central facility in Mangilao from class D (wooden) to class A (concrete).	DPHSS	$150,000	HMGP/PDM	1-2 years	High
32	Develop a RL property strategy to verify loss information, collect information about flood risks, and implement a mitigation program mitigate these properties. Mitigation efforts may include: retrofitting, elevating, and floodproofing structures.	DPW	TBD	TBD	1-2 years	High
33	Scope, gain NEPA approval, and develop final design for the most cost effective solution to restore Agueda River flow beneath Route 1, and mitigate flooding of Route 1 near the intersection of Polaris Point Road. This work would also include ROW acquisition as needed, and any required environmental permitting.	DPW	$3,600,000	HMGP/PDM/ GovGuam Funds	3 years	High
34	Retrofit Building 500 to harden Butler-tin structure by replacing with concrete envelope and to mitigate against storm strength wind events, to bring building up to electrical code, and to reduce loss of life, damage to surrounding buildings on campus from storms and typhoons, and to prevent disruption of educational training and services.	GCC	$4,000,000	HMGP/PDM/ Guam Community College Foundation	1-2 years	Low
35	Retrofit Building 600 to harden Butler-tin structure by replacing with concrete envelope and to mitigate against storm strength wind events, to bring building up to electrical code, and to reduce loss of life, damage to surrounding buildings on campus from storms and typhoons, and to prevent disruption of educational training and services.	GCC	$4,000,000	HMGP/PDM/ Guam Community College Foundation	1-2 years	Low

Table 6-4 Implementation Strategy

Action No.	Description	Primary Agency	Estimated Cost	Potential Funding Source**	Estimated Time Frame	Priority
36	Retrofit Building 900 to harden Butler-tin structure by replacing with concrete envelope and to mitigate against storm strength wind events, to bring building up to electrical code, and to reduce loss of life, damage to surrounding buildings on campus from storms and typhoons, and to prevent disruption of educational training and services.	GCC	$4,000,000	HMGP/PDM/ Guam Community College Foundation	1-2 years	Low
37	Mitigate the damages to GHC's rental units by providing typhoon shutters to all units within GHC's purview (i.e. Lada Estates, Sagan Linahyan and Guma As-Atdas).	GHC	TBD	HMGP/PDM/ GovGuam Funds	TBD	High
38	Mitigate flooding issues at Lada Estates, Dededo, due to the ponding basin being closed off to Lada Estates.	GHC, DPW	TBD	HMGP/PDM/ GovGuam Funds	TBD	Low
39	Convert existing overhead distribution primary and secondary power lines to an underground electrical system composed of manholes, handholes, conduits, underground power cables, splices, and accessories to eliminate typhoon hazard.	GPA	TBD	HMGP/PDM/ Revenue	30 years	Low
40	Clara St. Underground Conversion (Mongmong) Distribution primary and secondary power lines overhead to underground conversion in a system of manholes, handholes, and underground power cables and accessories.	GPA	$250,000	HMGP/PDM/ Revenue	1 year	High
41	Convert existing overhead transmission power lines to an underground electrical system composed of manholes, handholes, conduits, underground power cables, splices, and accessories to eliminate typhoon hazard.	GPA	TBD	HMGP/PDM/ Revenue	30 years	Low
42	Tumon Bay Lateral Conversion Distribution primary and secondary power lines overhead to underground conversion in a system of manholes, handholes, and underground power cables and accessories.	GPA	$7,280,000	HMGP/PDM/ Revenue	2 years	High

Table 6-4 Implementation Strategy

Action No.	Description	Primary Agency	Estimated Cost	Potential Funding Source**	Estimated Time Frame	Priority
43	Hardening of overhead primary lines to replace existing wood poles with concrete poles and conversion of overhead secondary to underground electrical system of conduits, handholes, underground cables and accessories.	GPA	TBD	HMGP/PDM/ Revenue	2 years	High
44	Kaiser Hybrid Conversion (Chichirica, Sta Barbara, Amates) Hardening of overhead primary lines to replace existing wood poles with concrete poles and conversion of overhead secondary to underground electrical system of conduits, handholes, underground cables and accessories.	GPA	$2,600,000	HMGP/PDM/ Revenue	2 years	High
45	Design and install backup generators for critical deepwells, booster pump stations, and sewer treatment plants including but not limited to generators, fuel storage systems, monitoring equipment, hardened building, automatic transfer switches, and other electrical equipment and appurtenances. This is to ensure constant water and wastewater services for island residents in the event of natural disasters.	GPA	TBD	HMGP/PDM/ Revenue	5 years	High
46	Kaiser Hybrid Conversion (San Antonio Avenue) Hardening of overhead primary lines to replace existing wood poles with concrete poles and conversion of overhead secondary to underground electrical system of conduits, handholes, underground cables and accessories.	GPA	$1,000,000	HMGP/PDM/ Revenue	2 years	High
47	Design and install backup generators for critical facilities such as school/housing shelters including but not limited to generators, fuel storage systems, monitoring equipment, hardened building, automatic transfer switches, and other electrical equipment and appurtenances.	GPA	TBD	HMGP/PDM/ Revenue	10 years	High

Table 6-4 Implementation Strategy

Action No.	Description	Primary Agency	Estimated Cost	Potential Funding Source**	Estimated Time Frame	Priority
48	Liguan Terrace Hybrid Conversion - Phase I Hardening of overhead primary lines to replace existing wood poles with concrete poles and conversion of overhead secondary to underground electrical system of conduits, handholes, underground cables and accessories.	GPA	$2,000,000	HMGP/PDM/ Revenue	3 years	High
49	Liguan Terrace Hybrid Conversion - Phase II Hardening of overhead primary lines to replace existing wood poles with concrete poles and conversion of overhead secondary to underground electrical system of conduits, handholes, underground cables and accessories.	GPA	$2,000,000	HMGP/PDM/ Revenue	3 years	High
50	Barrigada Village - Phase I Hardening of overhead primary lines to replace existing wood poles with concrete poles and conversion of overhead secondary to underground electrical system of conduits, handholes, underground cables and accessories.	GPA	$4,000,000	HMGP/PDM/ Revenue	4 years	High
51	Agana Heights - Phase I Hardening of overhead primary lines to replace existing wood poles with concrete poles and conversion of overhead secondary to underground electrical system of conduits, handholes, underground cables and accessories.	GPA	$4,000,000	HMGP/PDM/ Revenue	5 years	High
52	Yigo Village - Phase I Hardening of overhead primary lines to replace existing wood poles with concrete poles and conversion of overhead secondary to underground electrical system of conduits, handholes, underground cables and accessories.	GPA	$4,000,000	HMGP/PDM/ Revenue	5 years	High
53	Agana Village - Phase I Hardening of overhead primary lines to replace existing wood poles with concrete poles and conversion of overhead secondary to underground electrical system of conduits, handholes, underground cables and accessories.	GPA	$4,000,000	HMGP/PDM/ Revenue	5 years	High

Table 6-4 Implementation Strategy

Action No.	Description	Primary Agency	Estimated Cost	Potential Funding Source**	Estimated Time Frame	Priority
54	Tamuning Village - Phase I Hardening of overhead primary lines to replace existing wood poles with concrete poles and conversion of overhead secondary to underground electrical system of conduits, handholes, underground cables and accessories.	GPA	$4,000,000	HMGP/PDM/ Revenue	5 years	High
55	Harden PAG buildings and facilities with new windows, typhoon shutters and coiling doors, to conform to wind speed requirements found in the 2012 International Building Code.	PAG	$750,000	HMGP/PDM	2 years	High
56	Weatherize and harden dormitory buildings as follows Dormitory I - Building Number 637, Dormitory II - Building number 657, and Dormitory III - Building Number 679.	UOG	$350,000,000	HMGP/PDM	1 year	Low
57	Execute the Agana River Flood Control Project with the USACE. The project was original authorized under the WRDA of 1986 but was admiratively de-authorized in April 2002. A General Reevaluation Request is being considered by USACE.	DPW, BSP	10,000,000	USACE, USDOT, DPW	4 years	High
58	Develop a proposal to initiate flood and erosion mitigation option as proposed by USACE under Section 205 Flood Damage Reduction of the Continuing Authorities Program for Manell River, Umatac River, and Namo River.	DPW, BSP	10,000,000	USACE, USDOT, DOI, DOC	4 years	High
59	Implement mitigation actions indicated in the Agat Bay Regional Shoreline Assessment	PAG, DPR	10,000,000	PAG, DOC USACE, DOI DOC, GPA	4 years	High
60	Implement adaptive management interventions based on the best available science and reduce local pressures and increase coral reef resilience to climate change as described in the 2018 Coral Reef Resilience Strategy	DOAg	5,000,000	DOAg, CRI, CRCP, DOI BSP	4 years	High

6.5.3 Contribution to the Overall State Mitigation Strategy

As noted in **Section 6.4** (Mitigation Goals), the goals identified for the 2019 Guam HMP serve as the foundation of the Government of Guam's overall mitigation strategy. The 36 "high priority" mitigation measures identified in **Table 6-4** contribute to the Government of Guam's overall mitigation strategy by addressing all the six mitigation goals.

- 5 mitigation actions (#1, 3, 13, 21, and 32) will help improve the quality and comprehensiveness of information on assets and hazards
- 31 mitigation actions (#2, 3, 4, 8, 9, 10, 12, 16, 19, 28, 21, 33, 37, 40, 42, 43, 44, 45, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 57, and 58) will help reduce risks of disaster damage to existing buildings and infrastructure, especially EFMUTS
- 5 mitigation action (#13, 57, 58, 59, and 60) will help promote disaster-resistant development and disaster recovery
- 2 mitigation actions (#11, and 60) will help develop institutional support of hazard mitigation within Government of Guam agencies and the public
- 8 mitigation actions (#2, 3, 8, 9, 10, 16, 19, and 31) will help protect human health and safety
- 1 mitigation actions (#32) will help eliminate or reduce the damage to residential property and the disruption of life caused by repeated flooding

7.1 PURPOSE

The purpose of this section is to describe the formal process to ensure that the 2019 Guam HMP remains an active and relevant document. The plan maintenance process includes a schedule for monitoring and evaluating the Guam HMP and the mitigation measures annually and revising and updating the Guam HMP every 5 years. This process was revised during 2014 Guam HMP update to address shortfalls and streamline the plan maintenance procedures. Like the 2014 Guam HMP, the 2019 Guam HMP will continued to be monitored by the GHS/OCD on an annual basis and the HMAC will only convene after a major disaster and/or before the next 5-year HMP update. While the monitoring and evaluation process for the HMP update remain the same, a new update schedule has been developed to ensure a timely plan update process.

7.2 MONITORING, EVALUATING, AND UPDATING THE HMP

The DMA 2000 requirements for consideration by FEMA for the plan maintenance process are shown below and addressed in the following text.

DMA 2000 REQUIREMENTS – PLAN MAINTENANCE PROCESS - MONITORING, EVALUATING, AND UPDATING THE PLAN
Monitoring, Evaluating, and Updating the Plan Requirement § 201.4(c)(5)(i): *[The Standard State Plan Maintenance Process* ***must*** *include an] established method and schedule for monitoring, evaluating, and updating the plan*.
Element A. Does the new or updated plan describe the method and schedule for monitoring the plan? (i.e., identifies the party responsible for monitoring, includes schedule for reports, site visits, phone calls, and/or meetings) B. Does the new or updated plan describe the method and schedule for evaluating the plan? (i.e., identifies the party responsible for evaluating the plan, includes the criteria used to evaluate the plan) C. Does the new or updated plan describe the method and schedule for updating the plan? D. Does the updated plan include an analysis of whether the previously approved plan's method and schedule worked and what elements or processes, if any, were changed?
Source: FEMA 2008.

7.2.1 HMP Monitoring

The GHMO will continue to be responsible for the overall monitoring of the plan, including:

- Monitoring the implementation of the plan
- Confirming and clarifying the responsibilities assigned to the various agencies for implementing the mitigation actions listed in the implementation strategy
- Facilitating the acquisition of and securing the funding sources for the mitigation actions
- Monitoring and documenting the implementation of the mitigation actions (discussed in more detail below)
- Facilitating the plan revision process
- Notifying the public when specific key milestones are achieved (discussed in more detail below)

The GHMO and the GHS/OCD Planning and Mitigation staff will conduct an annual review to monitor progress in implementing the Guam HMP, particularly addressing the mitigation goals and implementation strategy after both the first year and the second year of adoption. A questionnaire has been developed to assist the GHMO and the GHS/OCD Planning and Mitigation staff in carrying out this process on an annual basis. As shown in **Appendix G (**Plan Maintenance Documents), the Annual Review Questionnaire will provide the basis for possible changes to the Guam HMP by refocusing on new or more threatening hazards, adjusting to changes to or increases in resource allocations, and engaging additional support for the plan implementation.

7.2.2 HMP Evaluation

As noted above, the GHMO and GHS/OCD Planning and Mitigation staff will evaluate the 2019 Guam HMP on an annual basis. Should a major disaster occur, the HMAC will convene during post-disaster recovery and determine if the 2019 Guam HMP appropriately anticipated the disaster damage and intensity. As a result of the major disaster, the HMAC may need to reevaluate the hazard profiles, vulnerability analyses, and capability assessment to verify if the hazard information in the Guam HMP accurately reflects the facts of the recent hazard event. The HMAC will also determine if any relevant mitigation actions necessary for the recovery efforts are not addressed as mitigation actions in the 2019 Guam HMP. Once the effects of the disaster have become clear, the range and priority of the specific hazard mitigation actions may be changed. In addition, the effectiveness of the implemented actions in mitigating damage or loss of life in the recent disaster will also be analyzed. Finally, as a result of the major disaster, mitigation projects or actions may be altered or initiated in ways that were not originally intended to occur under the 2019 Guam HMP.

7.2.3 HMP Update

The GHMO is responsible for updates to the Guam HMP. To comply with the DMA 2000, the GHMO, GHS/OCD, and HMAC will update the Guam HMP, the Governor will adopt the Guam HMP, and the GHMO will submit the Guam HMP to FEMA for official approval every 5 years. To update this document, the GHS/OCD will follow the Guam HMP update schedule listed in **Table 7-1**:

Table 7-1 Guam HMP Update Schedule

Action Item	Steps	Start (Months Prior to Re-Adoption)
Funding	Apply for PDM Grant funding or secure Government of Guam funding to update the Guam HMP	24-36
Section 1, Prerequisites	Readopt the Guam HMP by the Governor and/or the Lieutenant Governor of Guam by signature of Executive Order	0-1
Section 2, Background	No action needed	N/A
Section 3, Planning Process Documentation	Update HMAC membership Reconvene the HMAC to assist in the plan update Confirm previous and current program integration efforts Document entire plan update process	6
Section 4, Island Description	Document any changes to the Government of Guam Update population, GBS and EFMUTS data Gather and update information on tourism arrivals and building permits Document development trends, including a general discussion on military buildup	4-5
Section 5, Risk Assessment	Determine new hazards to be profiled and profile hazards Update previous occurrences for all hazards profiled Conduct vulnerability analysis using updated asset and hazard information, interpret analysis, and discuss new findings Update all figures	4-5
Section 6, Mitigation Strategy	Include new mitigation plans/policies in the capability assessment table Review and update available funding sources Review previous implementation strategy and determine status and relevancy for inclusion the new potential mitigation actions list Document completed mitigation actions in the plan maintenance section Incorporate new mitigation actions from state plans and policies based on the updated risk assessment developed by the HMAC and other interested organizations Prioritize mitigation actions for the implementation strategy Determine the implementation strategy for selected mitigation actions	2-3
Section 7, Plan Maintenance Process	Review the plan maintenance process with the GHMO to determine what worked and what did not work After discussion/analysis with the GHMO, revise the plan maintenance process, as needed	1-2
Section 8, References	Include new sources	1-2

7.3 MONITORING PROGRESS OF MITIGATION ACTIVITIES

The DMA 2000 requirements for consideration by FEMA for monitoring the progress of mitigation activities are shown below and addressed in the following text.

DMA 2000 REQUIREMENTS – PLAN MAINTENANCE PROCESS – MONITORING PROGRESS OF MITIGATION ACTIVITIES
Monitoring Progress of Mitigation Activities Requirement § 201.4(c)(5)(ii): *[The Standard State Plan Maintenance Process* ***must*** *include a] system for monitoring implementation of mitigation measures and project closeouts*. Requirement § 201.4(c)(5)(iii): *[The Standard State Plan Maintenance Process* ***must*** *include a] system for reviewing progress on achieving goals as well as activities and projects in the Mitigation Strategy*.
Element A. Does the new or updated plan describe how mitigation measures and project closeouts will be monitored? B. Does the new or updated plan identify a system for reviewing progress on achieving goals in the Mitigation Strategy? C. Does the new or updated plan identify a system for reviewing progress on implementing activities and projects of the Mitigation Strategy? D. Does the updated plan discuss if mitigation actions were implemented as planned? Source: FEMA 2008.

7.3.1 Monitoring of Mitigation Actions and Project Closeouts

The GHMO will continue to be responsible for the overall monitoring of the status of the implementation strategy for the 2019 Guam HMP. As a matter of policy and practice, the GHMO will continue to monitor through its quarterly reports requirement system any open PDM-funded mitigation projects and HMGP projects that were initially developed and implemented using Typhoon Halong, Typhoon Dolphin, Typhoon Mangkhut and Typhoon Wutip funding. As such, any agency or department with an open mitigation project will submit (or continue to submit) a quarterly report to the GHMO, as shown in **Appendix G (**Plan Maintenance Documents), and the GHMO will continue to monitor any open mitigation project throughout its lifespan. The GHMO has made an effort—and will continue to make an effort—to visit each project site, at least, four times (start, midpoint, completion, and closeout). On closeout, an agency or department that uses grant funding must also submit a Final Claim Form (shown in **Appendix G** [Plan Maintenance Documents]) to the GHMO.

7.3.2 Review of Progress on Implementing Mitigation Goals and Mitigation Actions

In its annual meeting, the GHMO and the GHS/OCD Mitigation staff will analyze completed and uncompleted mitigation projects. Likewise, after a major disaster, the HMAC will do the same. For a completed project, the party with primary responsibility for implementing that project will provide a summary of the project, the respective goals and objectives of the plan that were achieved, a description of whether the results of the action matched the intended results, and if implementation of the action was cost-effective. For projects that have not been completed, the agency with primary responsibility will provide an overview of the project that will include the current project status.

7.3.3 Implementation of 2014 Guam HMP Mitigation Actions

The 2014 Guam HMP identified 15 high-priority mitigation actions. As shown in **Table 6-2**, there are 32 ongoing mitigation actions and 1 completed mitigation action from the 2014 Guam HMP. All 32 mitigation actions not implemented over the past 5 years have been included in the 2019 Guam HMP's implementation strategy.

7.4 CONTINUED PUBLIC INVOLVEMENT

The Government of Guam is dedicated to direct public involvement in the continual reshaping and updating of the Guam HMP. Although the HMAC represents the public to some extent, the public is entitled to directly comment on and provide feedback regarding the updates and revisions to the plan. In compliance with DMA 2000, the 2019 Guam HMP and the various revision processes to the 2019 Guam HMP will be made accessible to the public.

Copies of the 2019 Guam HMP will continue to be available for review at the GHS/OCD and on the GHS/OCD website. All copies of the 2019 Guam HMP will list the address and phone number of the GHMO, who is responsible for monitoring public comments and accepting suggestions regarding plan revisions. The HMAC will identify opportunities to raise awareness in the community about the 2019 Guam HMP, hazards, and potential mitigation projects.

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Appendix A
Adoption Resolution

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Appendix B
FEMA Crosswalk

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Appendix C
Definitions

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100-hundred year floodplain. Also referred to as the Base Flood Elevation (BFE) and Special Flood Hazard Area. An area within a floodplain having a 1 percent or greater chance of flood occurrence in any given year.

Acquisition of hazard-prone structures. Local governments can acquire lands in high hazard areas through conservation easements, purchase of development rights, or outright purchase of property.

Actions. Specific actions that help achieve goals and objectives. Multiple mitigation actions may be defined to feed into an evaluation of the alternative actions.

Arson. The act of willfully and maliciously burning of property, especially with criminal or fraudulent intent.

Asset. Any natural or human-made feature that has value, including, but not limited to people; buildings; infrastructure like bridges, roads, and sewer and water systems; lifelines like electricity and communication resources; or environmental, cultural, or recreational features like parks, dunes, wetlands, or landmarks.

Base Flood Elevation (BFE). Elevation of the base flood in relation to a specified datum, such as the National Geodetic Vertical Datum of 1929. The BFE is used as a standard for the National Flood Insurance Program (NFIP).

Benefit-cost analysis. Benefit-cost analysis is a systematic, quantitative method of comparing the projected benefits to projected costs of a project or policy. It is used as a measure of cost effectiveness.

Best Management Practices. Appropriate, site-specific management techniques that maximize the benefits of land and natural resource management actions, while minimizing impacts.

Biological hazards. A hazard caused by the presence of any microorganism, virus, infectious substance, or biological product that may be engineered as a result of biotechnology or any naturally occurring microorganism, virus, infectious substance, or biological product, capable of causing death, disease, or other biological malfunction.

Bond. A debt obligation issued by states, cities, counties, and other governmental entities to raise money to pay for public projects, such as government facilities and infrastructure.

Building. A structure that is walled and roofed, principally above ground and permanently affixed to a site. The term includes a manufactured home on a permanent foundation on which the wheels and axles carry no weight.

Building codes. Regulations that set forth standards and requirements for the construction, maintenance, operation, occupancy, use, or appearance of buildings, premises, and dwelling units. Building codes can include standards for structures to withstand natural hazards.

Building/structure collapse. The failure and downfall of a structure. The collapse may result from a variety of natural causes such as hurricanes/typhoons, earthquakes, tornadoes, floods, or from manmade circumstances such as construction deficiencies, neglect, aging infrastructure, or acts of terrorism.

Capability assessment. An assessment that provides an inventory and analysis of a community or state’s current capacity to address the threats associated with hazards. The capability assessment attempts to identify and evaluate existing policies, regulations, programs, and practices that positively or negatively affect the community or state's vulnerability to hazards or specific threats.

Channel maintenance. Ensuring that flood channels, storm sewers, retaining ponds, etc. do not become blocked by debris, sedimentation, overgrowth, or structural failure. Coastal zone. The area along the shore where the ocean meets the land as the surface of the land rises above the ocean. This land/water interface includes barrier islands, estuaries, beaches, coastal wetlands, and land areas with direct drainage to the ocean.

Civil disobedience. The refusal to obey civil laws or decrees, usually taking the form of passive resistance. People practicing civil disobedience break a law because they consider the law unjust, want to call attention to its justice, and hope to bring about its repeal or amendment. They are also willing to accept a penalty for breaking the law.

Civil disturbance. When individuals or segments of the population create a situation, often a result of civil unrest, requiring a response from the emergency response community to protect lives and property. The disturbance may be small and isolated to a small area or be of a larger scale and exceeding the response capabilities of a jurisdiction. Activities are normally active (demonstrations, looting, riots) rather than passive (public speeches, sit-downs, marches).

Civil unrest. When a segment of the civil population indicates its discontent or dissatisfaction with existing political, social, or religious issues. The unrest may materialize as a civil disturbance or civil disobedience. Activities may be passive (public speeches, sit-downs, marches) or active (demonstrations, looting, riots).

Coastal erosion. The process of erosion of coastal areas via wave action, particularly due to high surf and storm surge caused by tropical storms (i.e., hurricanes, typhoons). May include damage to barrier islands, estuaries, beaches, coastal wetlands, and land areas with direct drainage to the ocean.

Coastal zone management regulations. Regulations enacted to control growth and protect natural resources along coastlines. Under the federal Coastal Zone Management Act enacted in 1972, states and local governments adopt coastal zone management regulations designed to preserve, protect, and, where possible, restore or enhance valuable natural coastal resources such as wetlands, floodplains, estuaries, beaches, dunes, barrier islands, and coral reefs, as well as the wildlife dependent on those habitats.

Comprehensive plan. A document, also known as a "general plan," covering the entire geographic area of a community and expressing community goals and objectives. The plan lays out the vision, policies, and strategies for the future of the community, including all of the physical elements that will determine the community's future development. This plan can discuss the community's desired physical development, desired rate and quantity of growth, community character, transportation services, location of growth, and siting of public facilities and transportation. In most states, the comprehensive plan has no authority in and of itself, but serves as a guide for community decision-making.

Consequences. The damage (full or partial), injuries, and losses of life, property, environment, and business that can be quantified by some unit of measure, often in economic or financial terms.

Construction of barriers around structures. Protective structures, such as berms and retaining walls, created by grading or filling areas with soil meant to keep flood waters from reaching buildings.

Cost-effectiveness. Cost-effectiveness is a key evaluation criterion for federal grant programs. Cost- effectiveness has several possible definitions, although for grant-making purposes the Federal Emergency Management Agency (FEMA) defines a cost-effective project as one whose long-term benefits exceed its costs. That is, a project should prevent more expected damage than it costs initially to fund the effort, which is done to ensure that limited public funds are used in the most efficient manner possible. Benefit-cost analysis is one way to illustrate that a project is cost-effective.

Essential Facilities, Major Utilities, and Transportation Systems. Buildings, facilities and infrastructure vital to the health, safety, and welfare of the population and the functioning of the community. For the purpose of this plan the following are considered EFMUTSs.

Essential Facilities are essential to the health and welfare of the whole population and are especially important following hazard events. Essential facilities include hospitals and other medical facilities, police and fire stations, emergency operations centers and evacuation shelters, and schools.

Major Utilities such as potable water, wastewater, and electric power systems.

Transportation Systems include airports, port facilities, bridges, traffic signals, and major roads.

FEMA’s HAZUS program includes two additional categories that are not included in this plan:

High Potential Loss Facilities are facilities that would have a high loss associated with them, such as nuclear power plants, dams, and military installations. Not included due to control of these facilities by the U.S. military.

Hazardous Material Facilities include facilities housing industrial/HAZMAT, such as corrosives, explosives, flammable materials, radioactive materials, and toxins. Not considered due to the control of most of these by the U.S. military or by private entities.

Dam/levee failure. Dam/levee failure can be caused by natural occurrences such as floods, rock slides, earthquakes, or the deterioration of the foundation or the materials used in construction. Usually the changes are slow and not readily discovered by visual examination. Such a failure presents a significant potential for a disaster in that significant loss of life and property would be expected in addition to the possible loss of power and water resources.

Dams. Dams are artificial barriers that impound water, wastewater, or any liquid-borne material for the purpose of storage or control of water. For a more detailed definition, see the National Dam Safety Program Act (as amended through Public Law 106-580, December 29, 2000).

Debris. The scattered remains of assets broken or destroyed in a hazard event. Debris caused by a wind or water hazard event can cause additional damage to other assets.

Density controls. Regulations that manage growth by limiting the density of development, often expressed in terms of the number of dwelling units per acre. Density controls allow the community to plan in an orderly way for infrastructure.

U.S. Department of Homeland Security (DHS). Following the September 11, 2001, terrorist attacks, President George W. Bush created a new federal government department to bring 22 previously separate domestic agencies together. The new department's first priority is protecting the nation against further terrorist attacks. Component agencies analyze threats and intelligence, guard borders and airports, protect critical infrastructure, and coordinate the response for future emergencies. The new department is organized into five major directorates: Border and Transportation Security; Emergency Preparedness and Response (EPR); Science and Technology; and Information Analysis and Infrastructure Protection; Management. In addition, several other critical agencies have been folded into the new department or are newly created. FEMA is the foundation of the EPR Directorate.

Design review standards. Guidelines enacted by local governments requiring new development to meet certain appearance and aesthetic standards and establishing a process by which local officials can examine site plans or structure blueprints to assess compliance with those standards. Design review standards can help ensure new development blends with existing buildings and the landscape or meet other priorities, including hazard loss reduction.

Design standards. A set of guidelines pertaining to the appearance and aesthetics of buildings or improvements that governs construction, alteration, demolition, or relocation of a building or improvement of land.

Disaster Mitigation Act of 2000 (DMA 2000). DMA 2000 (Public Law 106-390) is the latest legislation to improve the planning process. It was signed into law on October 30, 2000. This new legislation reinforces the importance of mitigation planning and emphasizes planning for disasters before they occur.

Drought. A drought occurs when water supplies cannot meet established demands. "Severe" to "extreme" drought conditions endanger livestock and crops, significantly reduce surface and ground water supplies, increase the potential risk for wildland fires, increase the potential for dust storms, and cause significant economic loss. Humid areas are more vulnerable than arid areas. Drought may not be constant or predictable and does not begin or end on any schedule.

Dune and beach restoration. Actions taken to reestablish dunes and beaches that serve as natural protection against coastal flooding and storm surge. Dune and beach restoration activities consist of replenishing sand, replanting protective vegetation, controlling or restricting foot and vehicle traffic, and constructing sand traps or wind barriers.

Earthquake. An earthquake is a naturally induced shaking of the ground, caused by the fracture and sliding of rock within the Earth's crust. The magnitude is determined by the dimensions of the rupturing fracture (fault) and the amount of displacement that takes place. The larger the fault surface and displacement, the greater the energy. In addition to deforming the rock near the fault, this energy produces the shaking and a variety of seismic waves that radiate throughout the Earth. Earthquake magnitude is measured using the Richter Scale and earthquake intensity is measured using the Modified Mercalli Intensity Scale.

Easements. Grant a right to use property, or restrict the landowner's right to use the property in a certain way.

Elevation of structures. Raising structures above the base flood elevation to protect structures

Emergency Preparedness and Response (EPR) Directorate. One of five major DHS Directorates that builds upon formerly independent FEMA. EPR is responsible for preparing for natural and man-made disasters through a comprehensive, risk-based emergency management program of preparedness, prevention, response, and recovery. This work incorporates the concept of disaster-resistant communities, including providing federal support for local governments that promote structures and communities that reduce the chances of being hit by disasters.

Emergency Response Plan. A document that contains information on the actions that may be taken by a governmental jurisdiction to protect people and property before, during, and after a disaster.

Emergency response services. The actions of first responders such as firefighters, police, and other emergency services personnel at the scene of a hazard event. The first responders take appropriate action to contain the hazard, protect property, conduct search and rescue operations, provide mass care, and ensure public safety.

Eminent domain. The right of a government to appropriate private property for public use, with adequate compensation to the owner.

Enemy attack. The use of aggressive action against an opponent in pursuit of an objective. An "enemy attack" is considered an attack of one sovereign government against another as either a declared or undeclared act of war.

Environmental review standards. Guidelines established to ensure new development adheres to certain construction and site design standards to minimize the impact on the environment.

Erosion. Wearing away of the land surface by detachment and movement of soil and rock fragments during a flood or storm over a period of years, through the action of wind, water, or other geologic processes.

Explosion/Fire. An explosion is the sudden loud release of energy and a rapidly expanding volume of gas that occurs when a gas explodes or a bomb detonates. Explosions result from the ignition of volatile products such as petroleum products, natural and other flammable gases, HAZMAT/chemicals, dust, and bombs. While an explosion surely may cause death, injury and property damage, a fire routinely follows, which may cause further damage and inhibit emergency response.

Exposure. The number, types, qualities, or monetary values of various types of property or infrastructure and life that may be subject to an undesirable or injurious hazard event.

Extreme air pollution. Pollution is the contamination of the earth's environment with materials that interfere with human health, the quality of life, or the natural functioning of ecosystems. Air pollution is the addition of harmful substances to the atmosphere. It makes people sick, causing breathing problems and sometimes cancer, and it harms plants, animals, and the ecosystems in which they live. Some pollutants return to earth in the form of acid rain and snow that corrodes structures, damage vegetation, and makes streams and lakes unsuitable for life. "Extreme air pollution" exceeds established thresholds resulting in the need to take corrective actions and cause the public to take precautions.

Extreme heat. Extreme heat is defined as temperatures that hover 10 degrees or more above the average high temperature for the region and last for several weeks. Humid conditions may also add to the discomfort of high temperatures.

Federal Emergency Management Agency (FEMA). Formerly independent agency created in 1978 to provide a single point of accountability for all federal activities related to disaster mitigation and emergency preparedness, response and recovery. As of March 2003, FEMA is a part of the DHS' EPR Directorate.

Fire-proofing. Actions taken on and around buildings to prevent the spread of fires.

Flood Hazard Area. The area on a map shown to be inundated by a flood of a given magnitude.

Flood Insurance Rate Map (FIRM) or Digital Flood Insurance Rate Map (DFIRM). Map of a community, prepared by FEMA that shows the special flood hazard areas and the risk premium zones applicable to the community.

Flood Mitigation Assistance (FMA) Program. A program created as part of the National Flood Insurance Reform Act of 1994. FMA provides funding to assist communities and states in implementing actions that reduce or eliminate the long-term risk of flood damage to buildings, manufactured homes, and other NFIP insurable structures, with a focus on repetitive loss properties.

Flood zone. A geographical area shown on a FIRM that reflects the severity or type of flooding in the area.

Floodplain development regulations. Regulations requiring flood insurance and mandating certain design aspects of new or substantially improved structures that lie within regulated flood-prone areas. Current federal regulations through the NFIP require that, at a minimum, new residential buildings in the Special Flood Hazard Area have their lowest floor at or above the base flood elevation.

Floodplain zoning. Zoning regulations that prescribe special uses for and serve to minimize development in floodplain areas.

Flood-proofing. Actions that prevent or minimize future flood damage. Making the areas below the anticipated flood level watertight or intentionally allowing floodwaters to enter the interior to equalize flood pressures are examples of flood proofing.

Floods. A general and temporary condition of partial or complete inundation of normally dry land areas from (1) the overflow of inland or tidal waters, (2) the unusual and rapid accumulation or runoff of surface waters from any sources, or (3) mudflows or the sudden collapse of shoreline land.

Forest and vegetation management. The management of forests and vegetation so they are resilient to landslides, high-winds, and other storm-related hazards.

Forest fire fuel reduction. Minimizing fuel loads in forested areas by clearing excess ground cover and thinning diseased or damaged woodland to create healthier forests and to decrease the vulnerability to the devastation of forest fire.

Frequency. A measure of how often events of a particular magnitude are expected to occur. Frequency describes how often a hazard of a specific magnitude, duration, and/or extent typically occurs, on average. Statistically, a hazard with a 100-year recurrence interval is expected to occur once every 100 years on average, and would have a 1 percent chance – its probability – of happening in any given year. The reliability of this information varies depending on the kind of hazard being considered. Probability is a related term.

Fuel/Resource shortage. A fuel/resource shortage is defined as an actual or potential shortage of natural gas, crude and refined petroleum, petroleum-derived fuels, or other critical commodities that significantly impacts the ability to: render essential government and emergency services (medical, fire, safety); and threatens the health and safety of the public.

Fujita scale of tornado intensity. Rates tornadoes with numeric values from F0 to F5 based on tornado winds peed and damage sustained. An F0 indicates minimal damage such as broken tree limbs or signs, while an F5 indicates severe damage sustained.

General obligation bond. A bond secured by the taxing and borrowing power of the municipality issuing it.

Geographic Information System (GIS). A computer software application that relates physical features on the earth to a database to be used for mapping and analysis.

Goals. General guidelines that explain what you want to achieve. Goals are usually broad statements with long-term perspective.

Hazard event. A specific occurrence of a particular type of hazard.

Hazard identification. The process of identifying hazards that threaten an area.

Hazard information center. Information booths, publication kiosks, exhibits, etc. that display information to educate the public about hazards that affect the jurisdiction and hazard mitigation activities people can undertake.

Hazard mitigation. Cost-effective measures taken to reduce or eliminate long-term risk from hazards and their effects.

Hazard Mitigation Grant Program (HMGP). Authorized under Section 404 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act, HMGP is administered by FEMA and provides grants to states, tribes, and local governments to implement hazard mitigation actions after a major disaster declaration. The purpose of the program is to reduce the loss of life and property due to natural disasters and to enable mitigation activities to be implemented as a community recovers from a disaster.

Hazard profile. A description of the physical characteristics of hazards and a determination of various descriptors, including magnitude, duration, frequency, probability, and extent. In most cases, a community can most easily use these descriptors when they are recorded and displayed as maps.

Hazard threat recognition. The process of identifying possible hazards and estimating potential consequences.

Hazard warning systems. Systems or equipment such as community sirens and National Oceanic Atmospheric Administration weather radios designed to provide advanced warning of an impending hazard. Warning systems allow communities to take protective actions before a hazard event occurs, including taking cover, finding shelter, or moving furniture, cars, and people out of harm's way.

Hazard. A source of potential danger or adverse condition. Hazards include both natural and man-made events. A natural event is a hazard when it has the potential to harm people or property and may include events such as floods, earthquakes, tsunami, typhoons, and wildland fires that strike populated areas. Man-made hazard events originate from human activity and may include technological hazards and terrorism. Technological hazards arise from human activities and are assumed to be accidental and/or have unintended consequences (i.e., manufacture, storage and use of HAZMAT). While no single definition of terrorism exists, the Code of Federal Regulations defines terrorism as "…unlawful use of force and violence against persons or property to intimidate or coerce a government, the civilian population, or any segment thereof, in furtherance of political or social objectives."

Hazardous materials incidents. A spilling, leaking, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping or disposing into the environment of a HAZMAT, but excludes: (1) any release that results in exposure to poisons solely within the workplace, with respect to claims that such persons may assert against the employer of such persons; (2) emissions from the engine exhaust of a motor vehicle, rolling stock, aircraft, vessel, or pipeline pumping station engine; (3) release of source, byproduct, or special nuclear material from a nuclear incident; and (4) the normal application of fertilizer.

Hazardous surf. Coastal or lake surf that is unusually high that overpower persons and small watercraft near or in the water. Often associated with rip currents. Typically the result of regional weather systems, such as high winds or tropical storms.

HAZUS, HAZUS-MH. A GIS-based, nationally standardized, loss estimation tool developed by FEMA. HAZUS-MH is the new multihazard version that includes earthquake, wind, hurricane, and flood loss estimate components.

Health and safety maintenance. Sections of emergency response/operations plans that provide for the security of affected areas, including clean up and special precautions for each type of hazard (i.e., draining standing water after a flood, cautioning about aftershocks after an earthquake or successive tsunami waves, etc.).

Hillside development regulations. Site design and engineering techniques prescribed through regulations such as selective grading, drainage improvements, and vegetation clearance to eliminate, minimize, or control development on hillsides, thereby protecting the natural features of hillsides and reducing the likelihood of property damage from landslides.

Hostage situation. A situation in which people are held hostage and negotiations take place for their release. The situation may range from a simple domestic or isolated criminal act to an attempt to impose will on a national or international scale to intimidate or coerce a government to further a political, social, or religious objective.

Hurricane. An intense tropical cyclone, formed in the atmosphere over warm ocean areas, in which wind speeds reach 74 miles per hour or more and blow in a large spiral around a relatively calm center or "eye." Hurricanes develop over the north Atlantic Ocean, northeast Pacific Ocean, or the southern Pacific Ocean east of 160ºE longitude. Hurricane circulation is counter-clockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere. See typhoon.

Hysteria (Mass). Also known as "mass psychogenic illness" and "hysterical contagion," mass hysteria is a situation in which a symptom or set of symptoms with no physical explanation spreads quickly among a group. It may occur as a reaction to an incident of domestic terrorism.

Implementation strategy. A comprehensive strategy that describes how the mitigation actions will be implemented.

Infestations. An infestation consists of an invasion or spreading of a living organism (plant, animal, etc.) that has an adverse (unwanted) effect on the population or the environment. The effect may range from a simple nuisance to an infectious disease or destructive parasite or insect.

Infestations may result from nonindigenous plants, rodents, weeds, parasites, insects, and fungi, and may adversely affect people, animals, agriculture, economy (i.e., tourism), and property.

Infrastructure. Refers to the public services of a community that have a direct impact on the quality of life. Infrastructure includes communication technology, such as phone lines or Internet access; vital services, such as public water supplies and sewer treatment facilities; and an area's transportation system. airports, heliports, highways, bridges, tunnels, roadbeds, overpasses, railways, bridges, rail yards, depots; and waterways, canals, locks, seaports, ferries, harbors, dry docks, piers, and regional dams.

Landslides/mudslides/debris flows. Landslides, like avalanches are massive downward and outward movements of slope-forming materials. The term landslide is restricted to movement of rock and soil and includes a broad range of velocities. Slow movements, although rarely a threat to life, can destroy buildings or break buried utility lines. A landslide occurs when a portion of a hill slope becomes too weak to support its own weight. The weakness is generally initiated when rainfall or some other source of water increases the water content of the slope, reducing the shear strength of the materials. A mud slide is a type of landslide referred to as a flow. Flows are landslides that behave like fluids: mud flows involve wet mud and debris.

Levees and floodwalls. Flood barriers constructed of compacted soil or reinforced concrete walls.

Liquefaction. The phenomenon that occurs when ground shaking (earthquake) causes loose soils to lose strength and act like viscous fluid. Liquefaction causes two types of ground failure: lateral spread and loss of bearing strength.

located in areas prone to flooding.

Loss estimation. Forecasts of human and economic impacts and property damage from future hazard events, based on current scientific and engineering knowledge.

Memorandum of Agreement. A nonbinding statement that defines the duties, responsibilities, and commitment of the different parties or individuals; provides a clear statement of values, principles, and goals; and establishes an organizational structure to assist in measuring and evaluating progress.

Mitigate. To cause to become less harsh or hostile; to make less severe or painful. Mitigation activities are actions taken to eliminate or reduce the probability of the event, or reduce its severity of consequences, either prior to or following a disaster/emergency.

Mitigation actions. Activities, measures, or projects that help achieve the goals and objectives of a mitigation plan.

Mitigation plan. A systematic evaluation of the nature and extent of vulnerability to the effects of natural hazards typically present in a defined geographic area, including a description of actions to minimize future vulnerability to hazards.

Modified Mercalli Intensity Scale. The Modified Mercalli Intensity Scale is commonly used in the United States by seismologists seeking information on the severity of earthquake effects. Intensity ratings are expressed as Roman numerals between I at the low end and XII at the high end. The Intensity Scale differs from the Richter Magnitude Scale in that the effects of any one earthquake vary greatly from place to place, so many Intensity values (i.e.,: IV, VII) may be measured from one earthquake. Each earthquake, on the other hand, should have just one

Magnitude, although the several methods of estimating it will yield slightly different values (i.e.,: 6.1, 6.3).

National Flood Insurance Program. Federal program created by Congress in 1968 that makes flood insurance available in communities that enact minimum floodplain management regulations as indicated in 44 CFR §60.3.

Objectives. Objectives define strategies or implementation steps to attain the identified goals. Unlike goals, objectives are specific and measurable.

Open space preservation. Preserving undeveloped areas from development through any number of methods, including low-density zoning, open space zoning, easements, or public or private acquisition. Open space preservation is a technique that can be used to prevent flood damage in flood-prone areas, land failures on steep slopes or liquefaction-prone soils, and can enhance the natural and beneficial functions of floodplains.

Ordinance. A term for a law or regulation adopted by a local government.

Performance standards. Standards setting the allowable effects or levels of impact of development. Often used in conjunction with traditional zoning, the standards typically address specific environmental conditions, traffic, or stormwater runoff. Can also be imposed on structures in hazard areas to ensure they withstand the effect of hazards.

Planning. The act or process of making or carrying out plans; the establishment of goals, policies, and procedures for a social or economic unit.

Planning team. A group composed of government, private sector, and individuals with a variety of skills and areas of expertise, usually appointed by a city or town manager, or chief elected official. The group finds solutions to community mitigation needs and seeks community acceptance of those solutions.

Policy. A course of action or specific rule of conduct to be followed in achieving goals and objectives.

Post-disaster mitigation. Mitigation actions taken after a disaster has occurred, usually during recovery and reconstruction.

Post-disaster recovery ordinance. An ordinance authorizing certain governmental actions to be taken during the immediate aftermath of a hazard event to expedite implementation of recovery and reconstruction actions identified in a pre-event plan.

Post-disaster recovery planning. The process of planning those steps the jurisdiction will take to implement long-term reconstruction with a primary goal of mitigating its exposure to future hazards. The post-disaster recovery planning process can also involve coordination with other types of plans and agencies, but it is distinct from planning for emergency operations.

Power/utility failure. A power/utility failure is defined as an actual or potential shortage of electric power or the interruption of electrical power that significantly threatens health and safety. Many communities are vulnerable to many localized, short and long-term energy emergencies. Power shortages or failures do occur and may be brought on by severe weather conditions, such as blizzards, ice storms, extreme heat, thunderstorms, or events such as war, or civil disturbance.

Private activity bond. A bond whose interest may or may not be federally taxable. Under the Internal Revenue Code, private activity bonds are described generally as any bond. (1) of which more than 10 percent of the proceeds is to be used in a trade or business of any person or persons other than a governmental unit, and which is to be directly or indirectly repaid, or secured by revenues from, a private trade or business; and (2) in which an amount exceeding the lesser of 5 percent or $5 million of the proceeds is to be used for loans to any person or persons other than a governmental unit. Certain private activity bonds are tax exempt when used to finance private water, wastewater, and multifamily housing projects.

Probability. A measure of how often events of a particular magnitude are expected to occur. Probability describes how often a hazard of a specific magnitude, duration, and/or extent typically occurs. Statistically, a hazard with a 100-year recurrence interval is expected to occur once every 100 years on average, and would have a 1 percent chance – its probability – of happening in any given year. The reliability of this information varies depending on the kind of hazard being considered. May also be measured in terms of the chance that an event will be exceeded (or not exceeded) over a specified period of time. Frequency is a related term.

Public education and outreach programs. Any campaign to make the public more aware of hazard mitigation and mitigation programs, including hazard information centers, mailings, public meetings, etc.

Q3 data. The Q3 Flood Data product is a digital representation of certain features of FEMA's FIRM product, intended for use with desktop mapping and GIS technology. The digital Q3 Flood Data are created by scanning the effective FIRM paper maps and digitizing selected features and lines. The digital Q3 Flood Data are designed to serve FEMA's needs for disaster response activities, NFIP activities, risk assessment, and floodplain management.

Radiological accident. A radiological accident is a release of radioactive materials. It can occur where radioactive materials are used, stored, or transported. Potentially nuclear power plants (fixed nuclear facilities), hospitals, universities, research laboratories, industries, major highways, railroads, or shipping yards could be the site of a radiological accident.

Radon. Radon is a naturally occurring radioactive gas that is odorless and tasteless. It is formed from the radioactive decay of uranium. Uranium is found in small amounts in most rocks and soil. It slowly breaks down to other products such as radium, which breaks down to radon. Radon also undergoes radioactive decay. Radon enters the environment from the soil, from uranium and phosphate mines, and from coal combustion. Radon has a radioactive half-life and about 4 days, meaning that one-half of a given amount of radon will decay to other products every 4 days. Some of the radon produced in the soil will move to the surface and enter the air. Radon also moves from the soil and enters the groundwater.

Real estate disclosure. Laws requiring the buyer and lender to be notified if a property is located in a hazard-prone area.

Regulation. Most states have granted local jurisdictions broad regulatory powers to enable the enactment and enforcement of ordinances that deal with public health, safety, and welfare. These include building codes, building inspections, zoning, floodplain and subdivision ordinances, and growth management initiatives.

Relocation out of hazard areas. A mitigation technique that features the process of demolishing or moving a building to a new location outside the hazard area.

Repetitive loss property. A property that is currently insured for which two or more NFIP losses (occurring more than 10 days apart) of at least $1000 each have been paid within any 10-year period since 1978.

Reservoirs. Large water storage facilities that can be used to hold water during peak runoff periods for controlled release during off-peak periods.

Resolutions. Expressions of a governing body's opinion, will, or intention that can be executive or administrative in nature. Most planning documents must undergo a council resolution, which must be supported in an official vote by a majority of representatives to be adopted. Other methods of making a statement or announcement about a particular issue or topic include proclamations and declarations.

Resources. Resources include the people, materials, technologies, money, etc., required to implement strategies or processes. The costs of these resources are often included in a budget. See definition for structural retrofitting.

Richter Magnitude Scale. A logarithmic scale devised by seismologist C. F. Richter in 1935 to express the total amount of energy released by an earthquake. While the scale has no upper limit, values are typically between 1 and 9, and each increase of 1 represents a 32-fold increase in released energy.

Rip current. A rip current is a shallow river or channel of water on the surface of the ocean. Special weather conditions can cause rip currents to form, particularly strong winds blowing toward the shore, which causes water pressure to build up on sandbars, reefs, or rocks.

Risk. The estimated impact that a hazard would have on people, services, facilities, and structures in a community; the likelihood of a hazard event resulting in an adverse condition that causes injury or damage. Risk is often expressed in relative terms such as a high, moderate, or low likelihood of sustaining damage above a particular threshold due to a specific type of hazard event. It also can be expressed in terms of potential monetary losses associated with the intensity of the hazard.

Risk assessment. A process or method for evaluating risk associated with a specific hazard and defined in terms of probability and frequency of occurrence, magnitude and severity, exposure, and consequences.

Sabotage. Sabotage is the deliberate destruction of property, dismantling of technology or other interference or obstruction of normal operations. "Sabotage" is normally considered an act related to war; similar acts during "nonwar" conditions would be considered a terrorist act.

Safe room/shelter. A small interior room constructed above grade and used to provide protection from tornadoes and other severe storm events. Bathrooms and large closets often double as safe rooms.

Seawalls/bulkheads. Vertical coastal walls that are built and designed to protect buildings against shoreline erosion. May also protect against storm surge.

Sediment and erosion control regulations. Regulations that stipulate the amount of sediment and erosion that is acceptable for land undergoing development.

Shoreline setback regulations. Regulations that establish a minimum distance between the existing shoreline and buildable areas.

Special events. An event of such a magnitude, media visibility, or importance that may require extraordinary preparations by government and possible response by emergency response agencies. Such events may be considered an opportunity or target for activist or terrorist activities.

Special tax bond. A bond secured by the pledge of a specific special tax.

Special use permits. Permits granted by local governments for land uses that have the potential for creating conflicts with uses on adjacent properties.

Stafford Act. The Robert T. Stafford Disaster Relief and Emergency Assistance Act, PL 100-107 was signed into law November 23, 1988, and amended the Disaster Relief Act of 1974, PL 93-288. The Stafford Act is the statutory authority for most federal disaster response activities, especially as they pertain to FEMA and its programs.

Stakeholder. Individual or group that will be affected in any way by an action or policy. Stakeholders include businesses, private organizations, and citizens.

State Hazard Mitigation Officer. The representative of state government who is the primary point of contact with FEMA, other state and federal agencies, and local units of government in the planning and implementation of pre- and post-disaster mitigation activities.

Storm surge. Rise in the water surface above normal water level on the open coast due to the action of wind stress and atmospheric pressure on the water surface.

Stormwater management regulations. Regulations governing the maintenance and improvement of urban stormwater systems and the implementation of land treatment actions to minimize the effects of surface water runoff. Land treatment actions include maintenance of vegetative cover, terracing, and slope stabilization.

Strategy. Collection of actions to achieve goals and objectives.

Stream corridor restoration. The restoration of the areas bordering creeks, including the stream bank and vegetation.

Stream dumping regulations. Regulations prohibiting dumping in the community's drainage system, thereby maintaining stream carrying capacities and reducing the possibility of localized flooding.

Strike. A strike is an organized work stoppage carried out by a group of employees for the purpose either of enforcing demands relating to employment conditions on their employer or of protesting unfair labor practices. A strike may be engaged to obtain improvement in work conditions, higher wages or shorter hours, to forestall an adverse change in conditions of employment, or to prevent the employer from carrying out actions viewed by workers as detrimental to their interests.

Structural retrofitting. Modifying existing buildings and infrastructure to protect them from hazards.

Subdivision and development regulations. Regulations and standards governing the division of land for development or sale. Subdivision regulations can control the configuration of parcels, set standards for developer-built infrastructure, and set standards for minimizing runoff, impervious surfaces, and sediment during development. They can be used to minimize exposure of buildings and infrastructure to hazards.

Subdivision. The division of a tract of land into two or more lots for sale or development.

Subsidence. Land subsidence occurs when large amounts of ground water have been withdrawn from certain types of rocks, such as fine-grained sediments. The rock compacts because the water is partly responsible for holding the ground up. When the water is withdrawn, the rocks fall in on itself.

Substantial damage. Damage of any origin sustained by a structure in a Special Flood Hazard Area whereby the cost of restoring the structure to its before-damaged condition would equal or exceeds 50 percent of the market value of the structure before the damage.

Taxation. Taxes and special assessments can be an important source of revenue for governments to help pay for mitigation activities. The power of taxation can also have a profound impact on the pattern of development in local communities. Special tax districts, for example, can be used to discourage intensive development in hazard-prone areas.

Terrorism (economic, cyber, nuclear, biological, and chemical). "Terrorism is the unlawful use of force or violence, or threatened use of force or violence, against persons and places for the purpose of intimidation and/or coercing a government, its citizens, or any segment thereof for political or social goals." (Department of Justice, Federal Bureau of Investigation). Terrorism can include computer-based (cyber) attacks and the use of weapons of mass destruction to include chemical, biological, radiological, nuclear, or explosive agents.

Thunderstorms/high winds. Thunderstorms are characterized as violent storms that typically are associated with high winds, dust storms, heavy rainfall, hail, lightning strikes, and/or tornadoes. The unpredictability of thunderstorms, particularly their formation and the rapid movement to new locations heightens the possibility of floods.

Tornadoes/dust devils. A tornado is a violently rotating column of air extending from a thunderstorm to the ground. The most violent tornadoes are capable of tremendous destruction with wind speeds in excess of 250 mph. Damage paths can exceed a mile wide and 50 miles long. Tornadoes are one of nature's most violent storms. In an average year, 800 tornadoes are reported across the United States, resulting in 80 deaths and over 1,500 injuries. The damage from tornadoes is due to high winds. The Fujita Scale of Tornado Intensity measures tornado/high wind intensity and damage. A dust devil is a small but rapidly rotating column of wind made visible by the dust, sand, and debris it picks up from the surface. They typically develop best on clear, dry, hot afternoons.

Transfer of development rights. A growth management technique through which development rights are transferred from a designated "sending" area to a designated "receiving" area. The sending area is generally prohibited from development and the receiving area is a targeted development area that can be built at a higher density.

Transportation accident. A transportation accident is an incident related to a mode of transportation (highway, air, waterway, port, and harbor) where an emergency response is necessary to protect life and property.

Tropical storm. A tropical system in which the maximum sustained surface wind ranges from 34 to 63 knots (39 to 73 mph). Tropical storms are associated with heavy rain, high wind, and thunderstorms. High intensity rainfall in short periods is typical. A tropical storm is classified as a hurricane/typhoon when its sustained winds reach or exceed 74 mph (64 knots). These storms are medium to large in size and are capable of producing dangerous winds, torrential rains, and flooding, all of which may result in tremendous property damage and loss of life, primarily in coastal populated areas. The effects are typically most dangerous before a hurricane/typhoon makes landfall, when most damage occurs.

Tsunami. Great sea wave produced by submarine earth movement or volcanic eruption.

Typhoon A special category of tropical cyclone peculiar to the North Pacific Basin, frequently affecting areas in the vicinity of Guam and the North Mariana Islands. Typhoons whose maximum sustained winds attain or exceed 150 mph are called super typhoons.

Urban forestry and landscape management. Forestry management techniques that promote the conservation of forests and related natural resources in urbanized areas, with a focus on obtaining the highest social, environmental, and economic benefits.

Volcanoes. A volcano is a vent in the Earth from which molten rock (magma) and gas erupt. The molten rock that erupts from the volcano (lava) forms a hill or mountain around the vent. The lava may flow out as a viscous liquid, or it may explode from the vent as solid or liquid particles. Volcanic eruptions can be placed into two general categories: those that are explosive and those that are effusive resulting in gently flowing lava flows, spatter cones, and lava fountains. Many eruptions are highly explosive in nature. They produce fragmental rocks from erupting lava and surrounding area rock and may produce fine volcanic ash that rises many kilometers into the atmosphere in enormous eruption columns. Explosive activity can also cause widespread ash fall, pyroclastic flows, debris avalanches, landslides, pyroclastic surges, and lahars.

Vulnerability. Describes how exposed or susceptible to damage an asset is. Vulnerability depends on an asset’s construction, contents, and the economic value of its functions. Like indirect damage, the vulnerability of one element of the community is often related to the vulnerability of another. For example, many businesses depend on uninterrupted electrical power–if an electric substation is flooded, it will affect not only the substation itself, but a number of businesses as well. Often, indirect effects can be much more widespread and damaging than direct effects.

Vulnerability assessment/analysis. The extent of injury and damage that may result from a hazard event of a given intensity in a given area. The vulnerability analysis should address impacts of hazard events on the existing and future built environment.

Vulnerable populations. Any segment of the population that is more vulnerable to the effects of hazards because of things such as lack of mobility, sensitivity to environmental factors, or physical abilities. These populations can include, but are not limited to, senior citizens and school children.

Wave run-up. The height that the wave extends up to on steep shorelines, measured above a reference level (the normal height of the sea, corrected to the state of the tide at the time of wave arrival).

Wetlands development regulations. Regulations designed to preserve and/or minimize the impact of development on wetlands.

Wildland fires. Wildland fire is a rapid, persistent chemical reaction that releases heat and light, especially the exothermic combination of a combustible substance with oxygen. Combine severe burning conditions with people or lightning and the stage is set for the occurrence of large, destructive wildland fires.

Wind-proofing. Modification of design and construction of buildings to withstand wind damage.

Zoning. The division of land within a local jurisdiction by local legislative regulation into zones of allowable types and intensities of land uses.

Zoning or land use map. A map that identifies the various zoning district boundaries and the uses permitted by a zoning ordinance within those boundaries.

Zoning ordinance. Designation of allowable land use and intensities for a local jurisdiction. Zoning ordinances consist of two components: a zoning text and a zoning map.

Appendix D
Figures

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Data sources:
Government of Guam; USGS; NOAA; USDA Forest Service;
University of Guam; Pacific Marine Environmental Lab; Tracey et. al, 1964

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Figure D-1
Major features

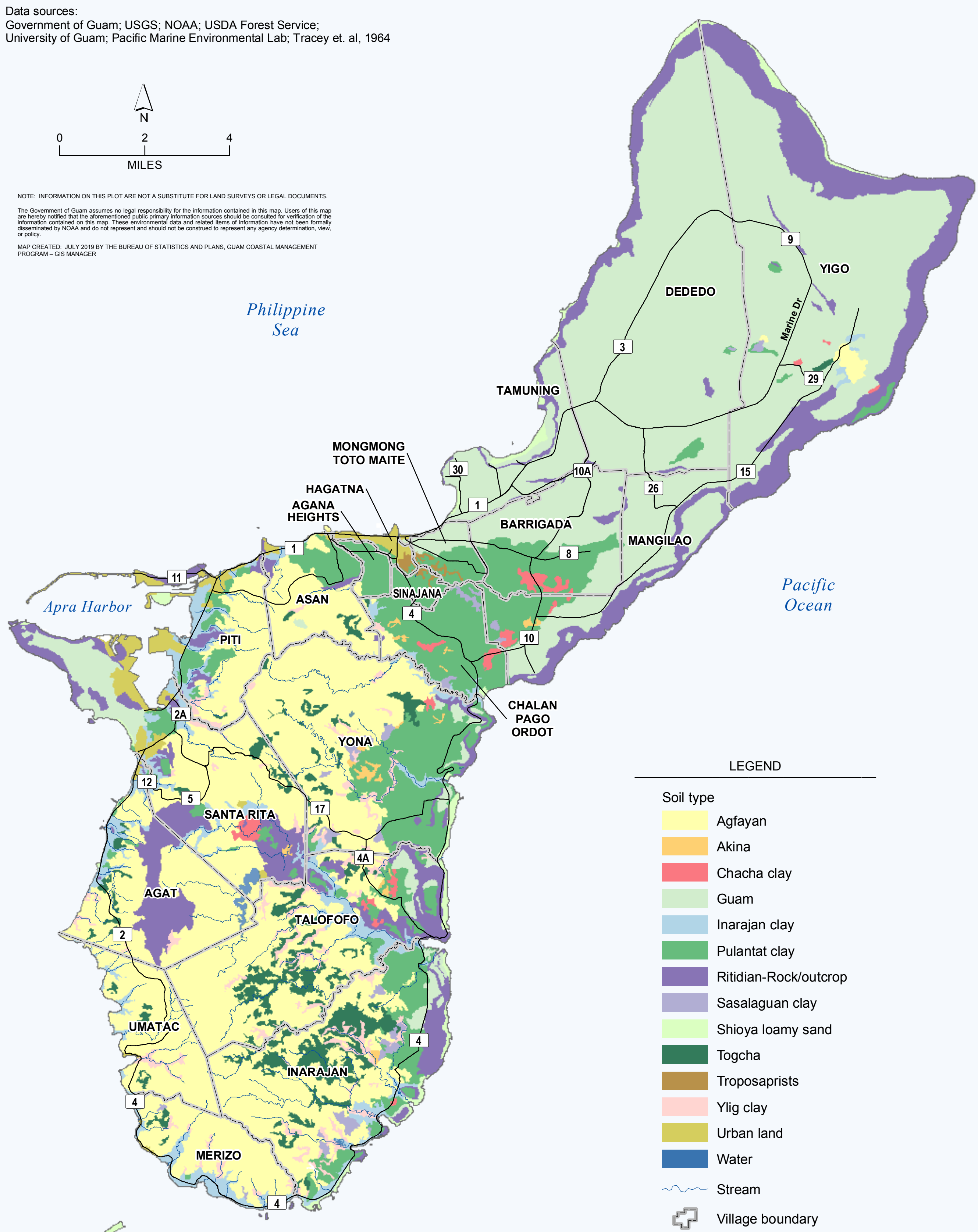

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Figure D-2
Soils

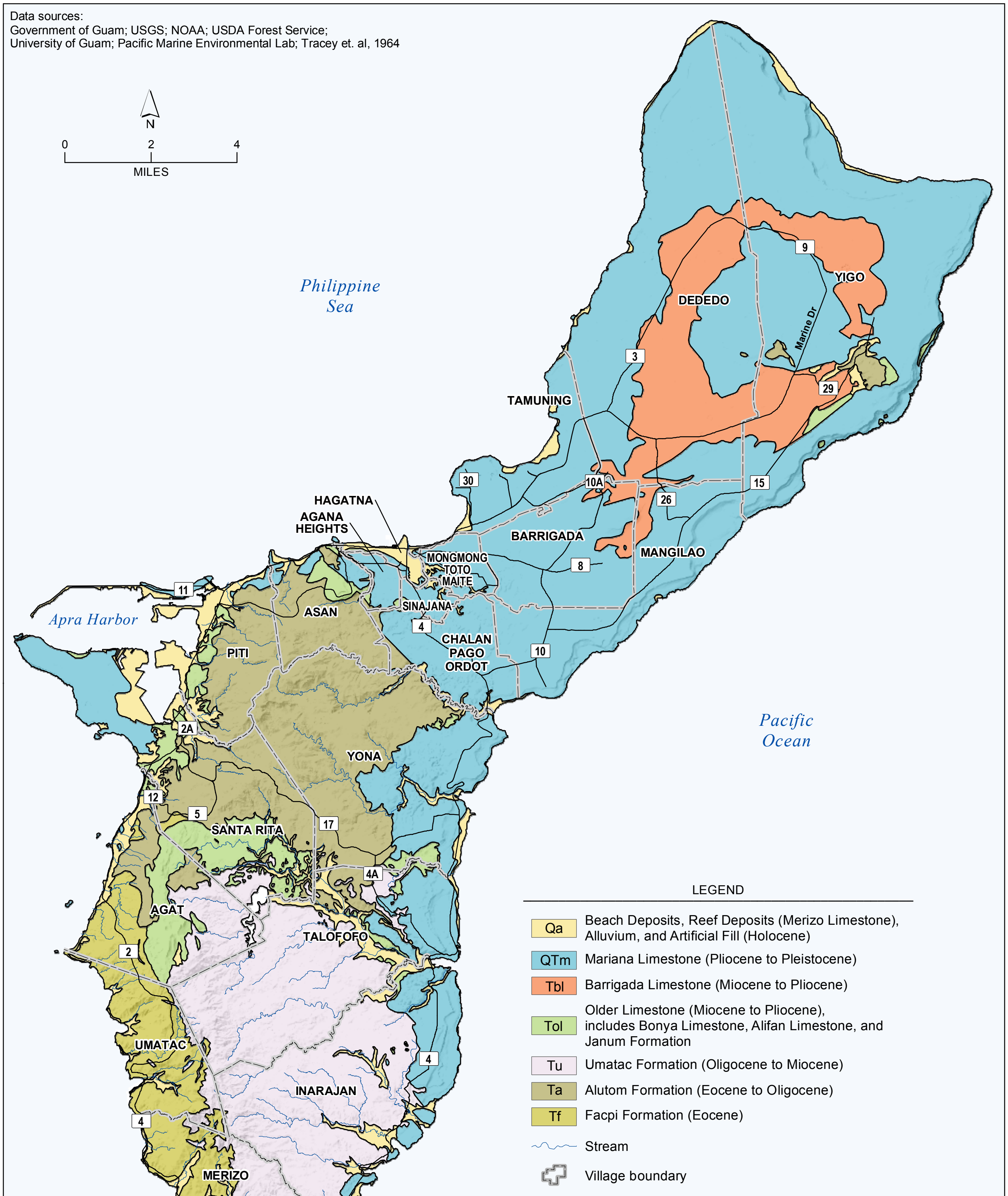

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Figure D-3
Geology

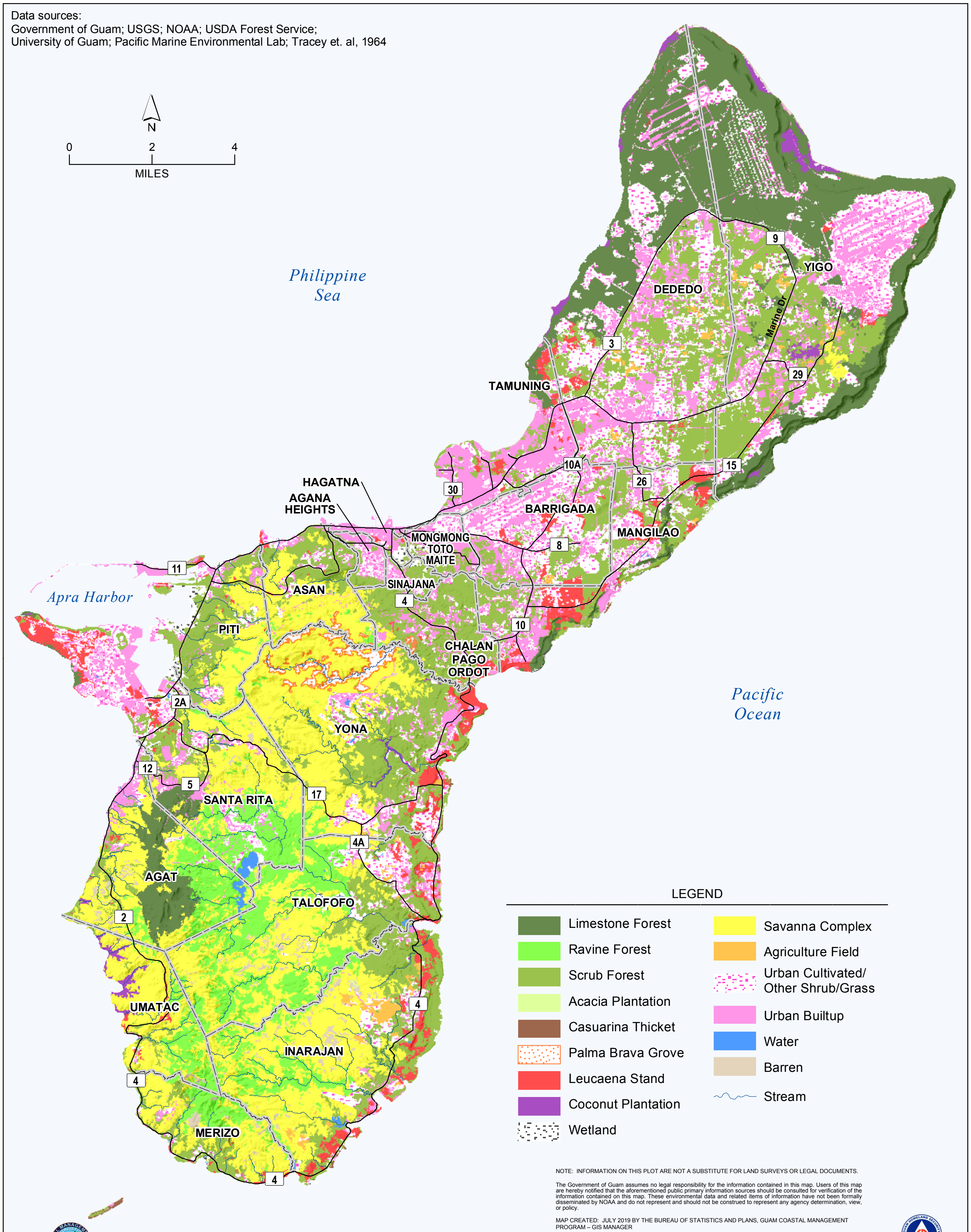

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Figure D-4
Vegetation

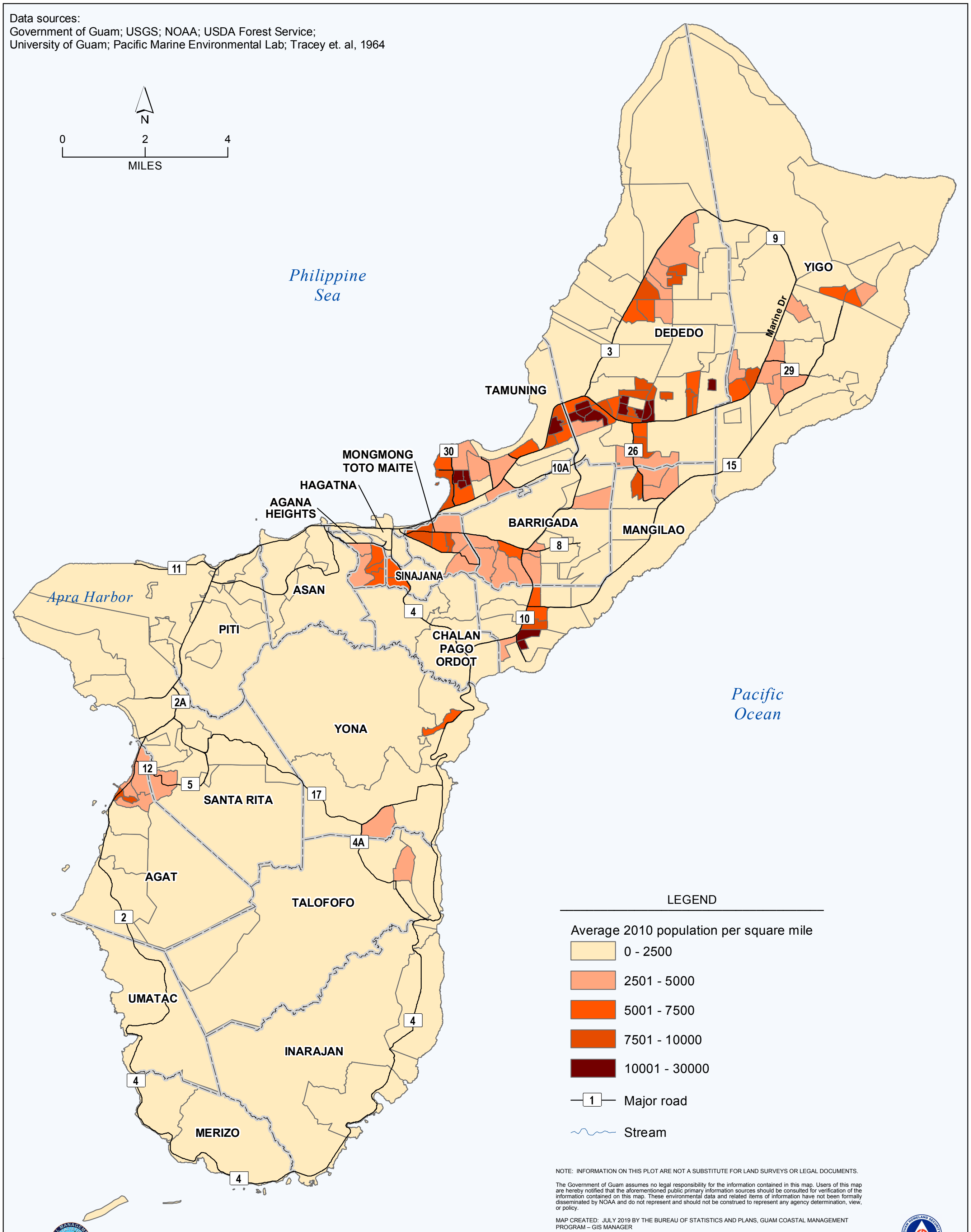

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Figure D-5
Population density

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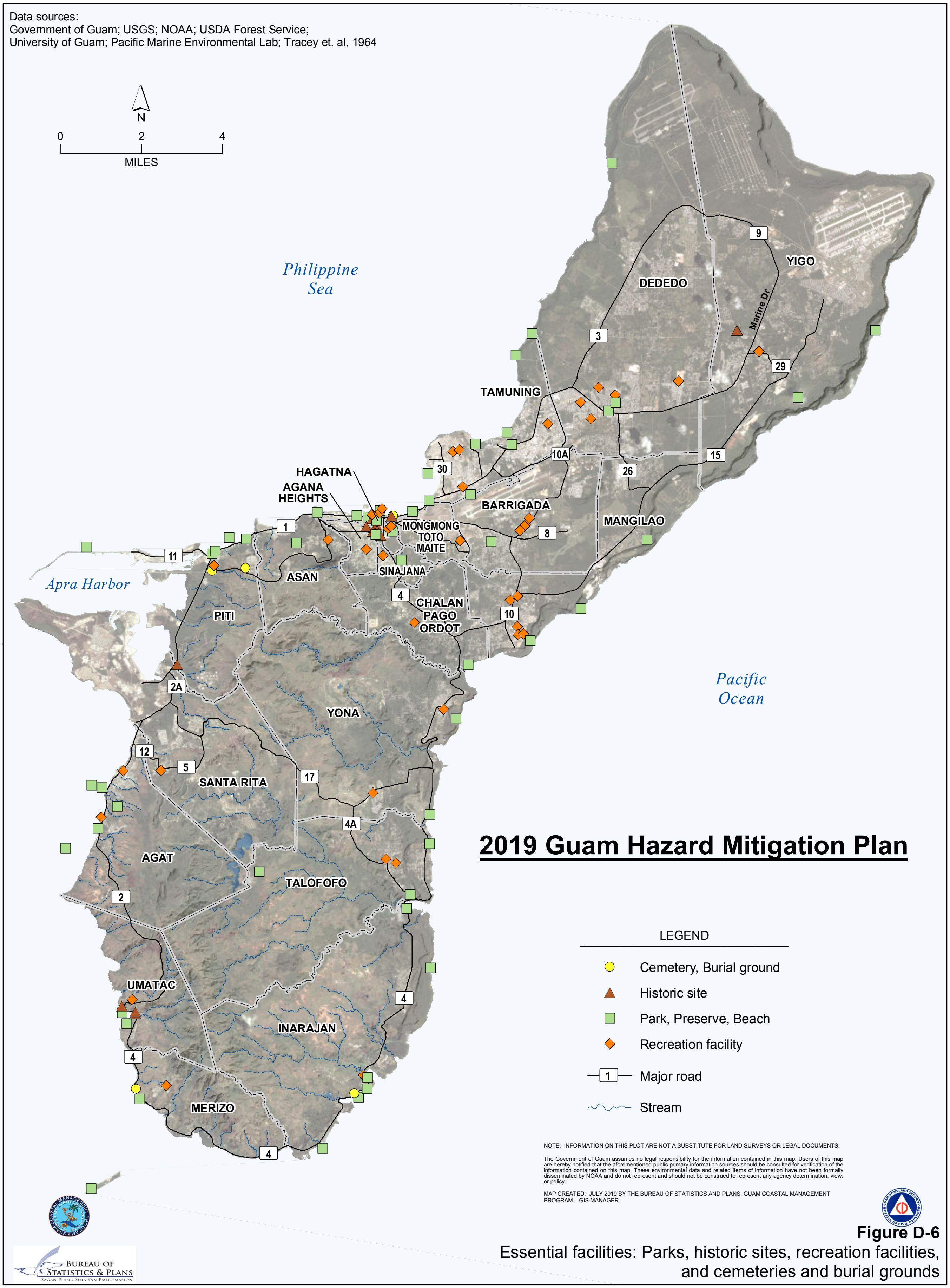

Figure D-6

Essential facilities: Parks, historic sites, recreation facilities, and cemeteries and burial grounds

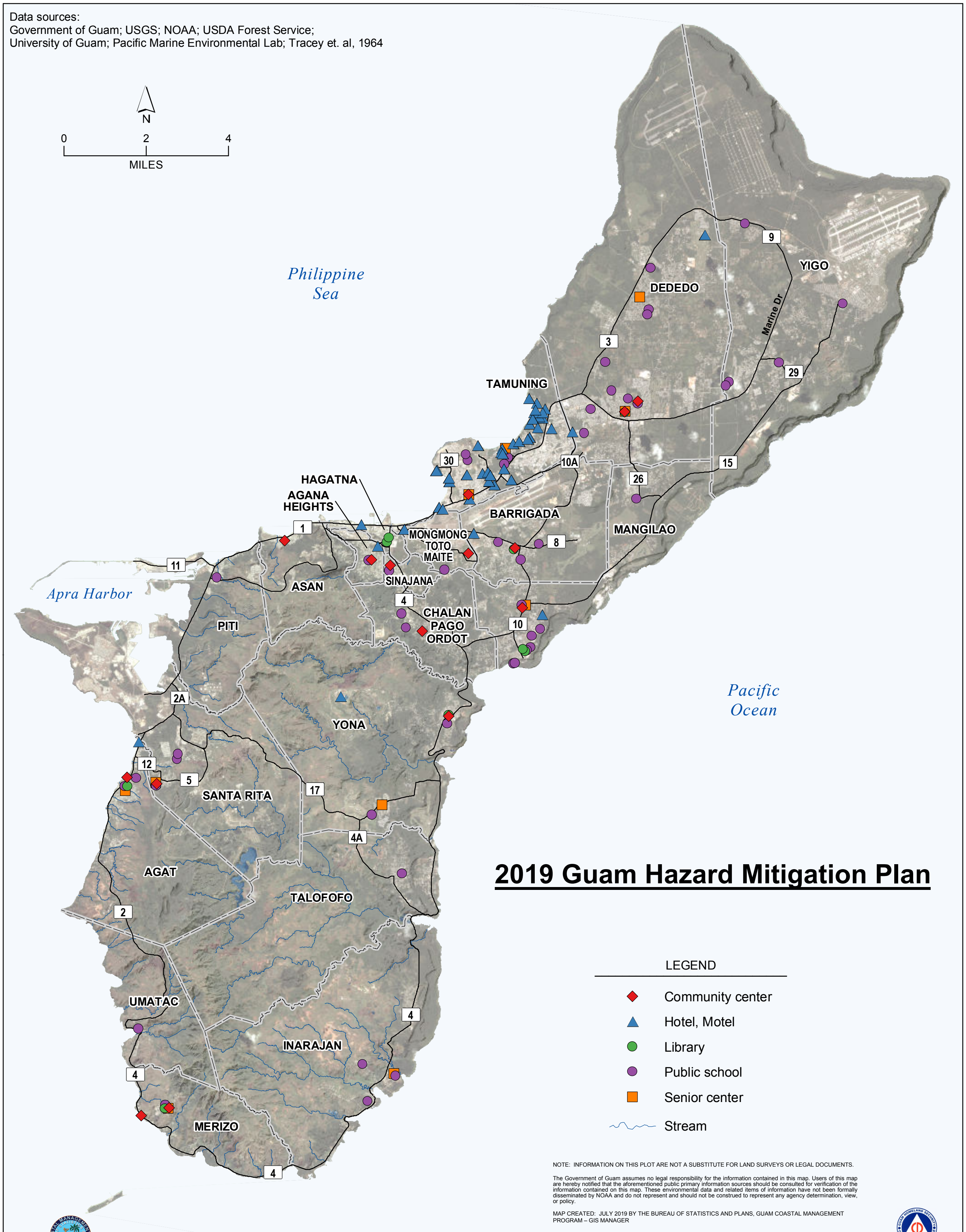

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Figure D-7

Essential facilities: Community centers, public schools, libraries, and hotels and motels

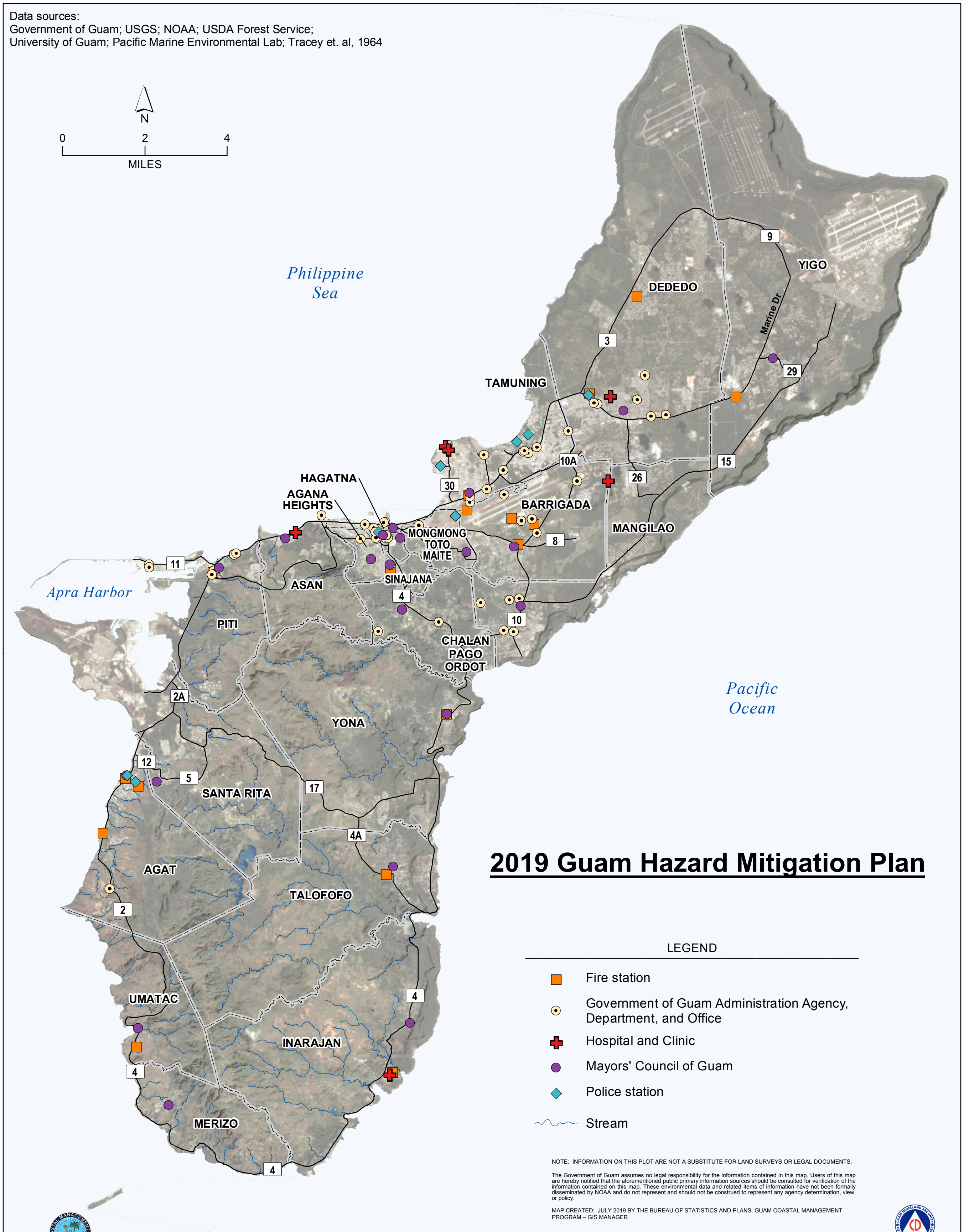

Figure D-8
Essential facilities: Emergency response and Government of Guam facilities

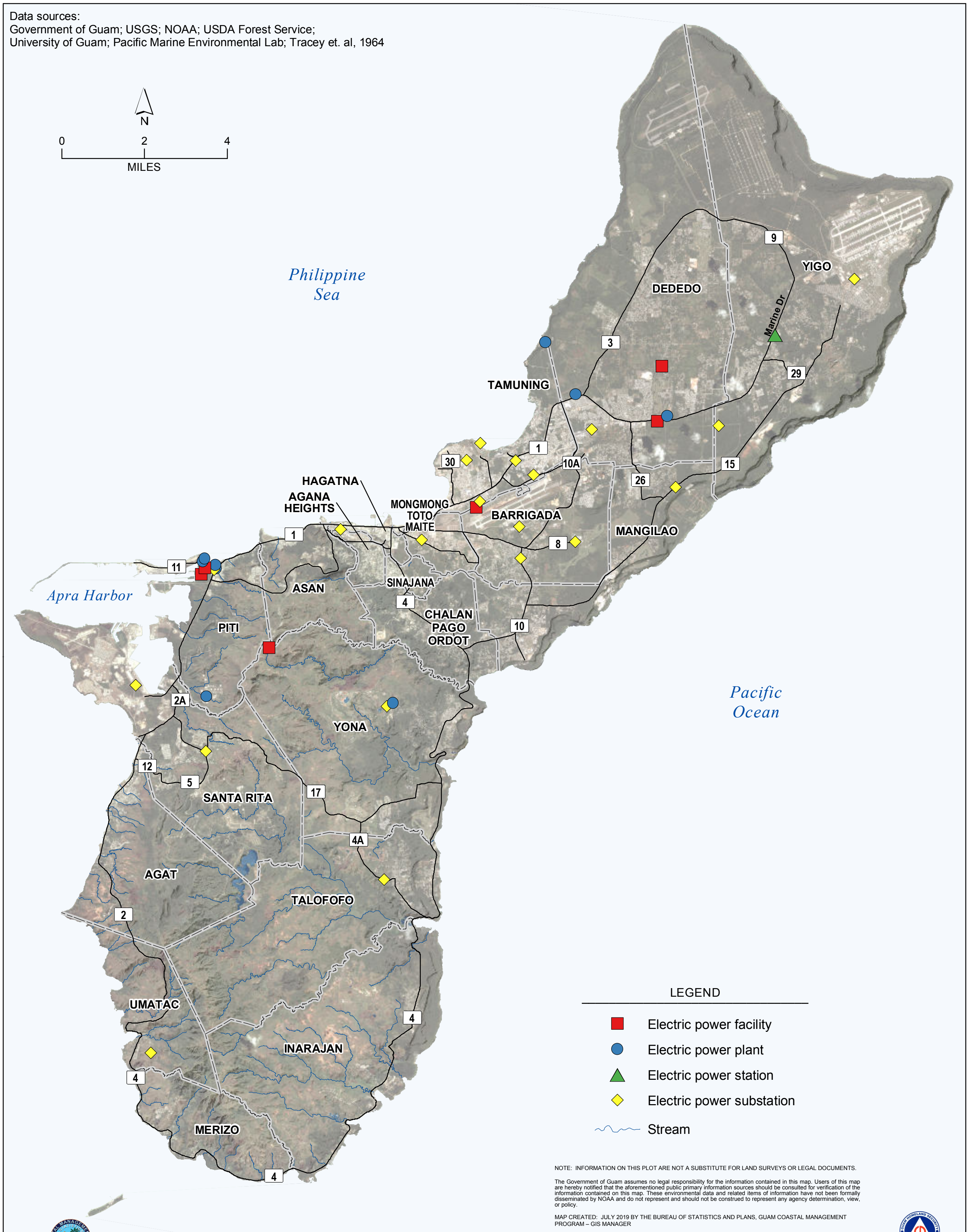

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Figure D-9
Major utilities:
Electric power facilities

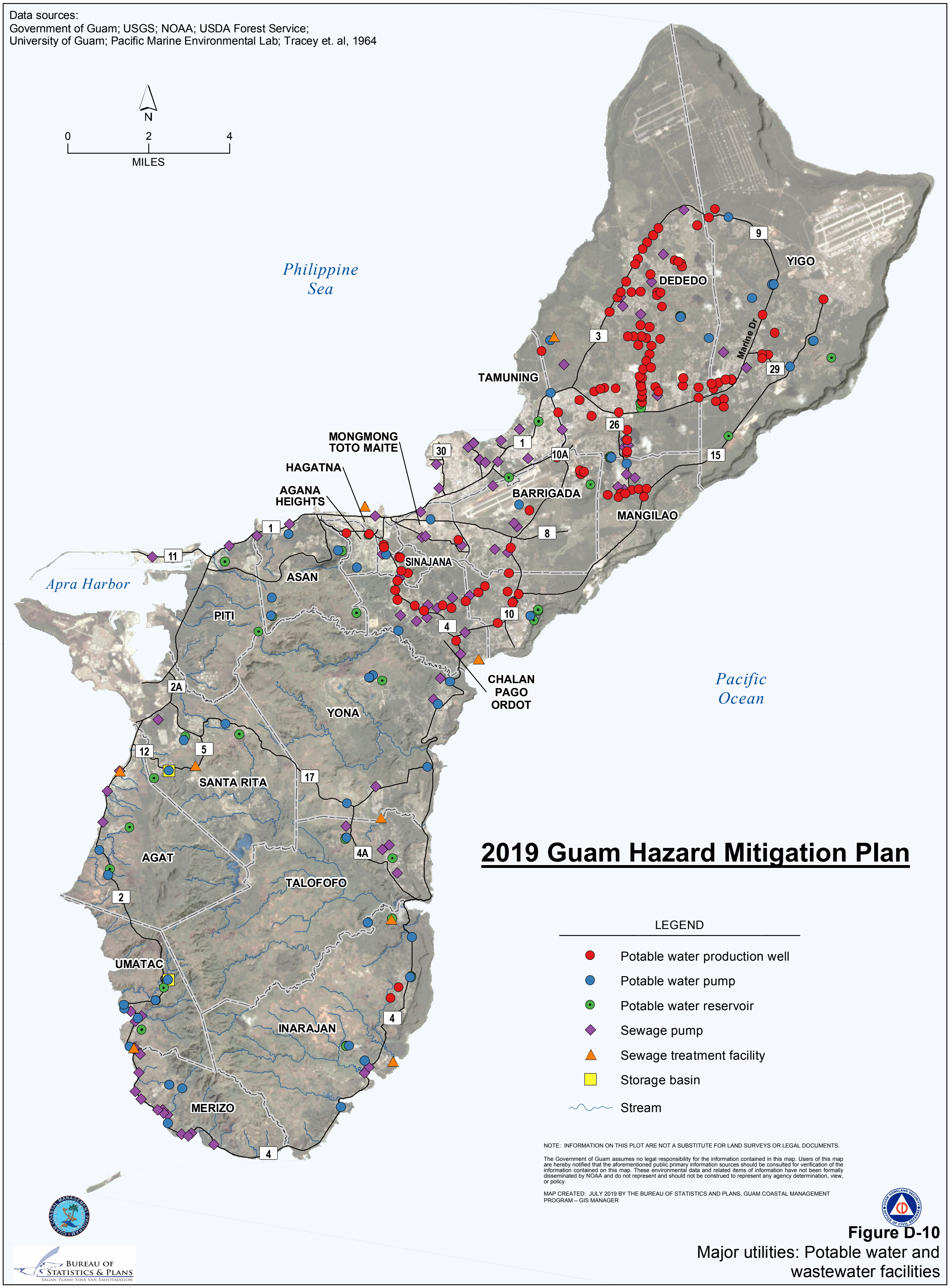

Figure D-10
Major utilities: Potable water and wastewater facilities

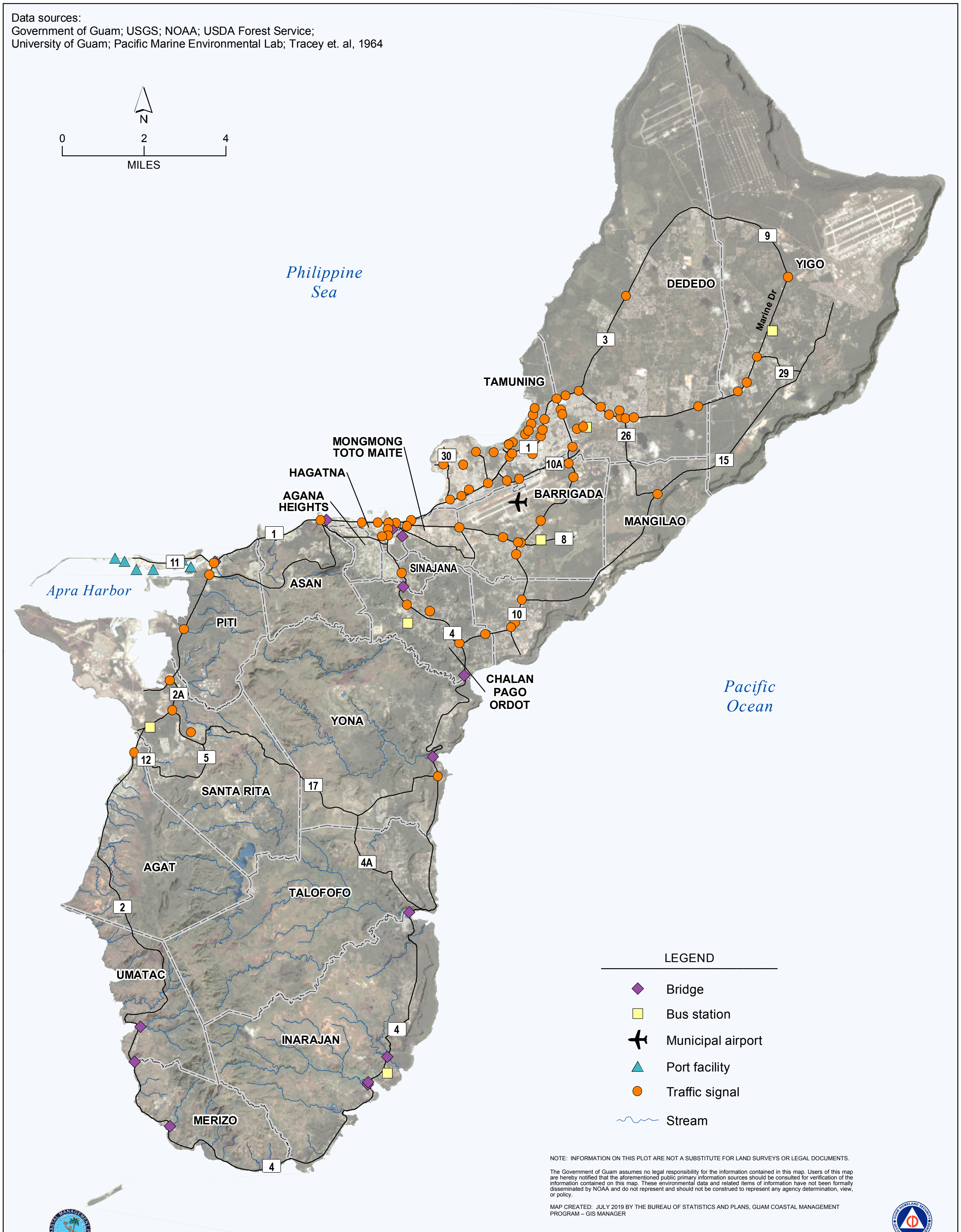

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Figure D-11
Transportation systems

Data sources:
Government of Guam; USGS; NOAA; USDA Forest Service;
University of Guam; Pacific Marine Environmental Lab; Tracey et. al, 1964

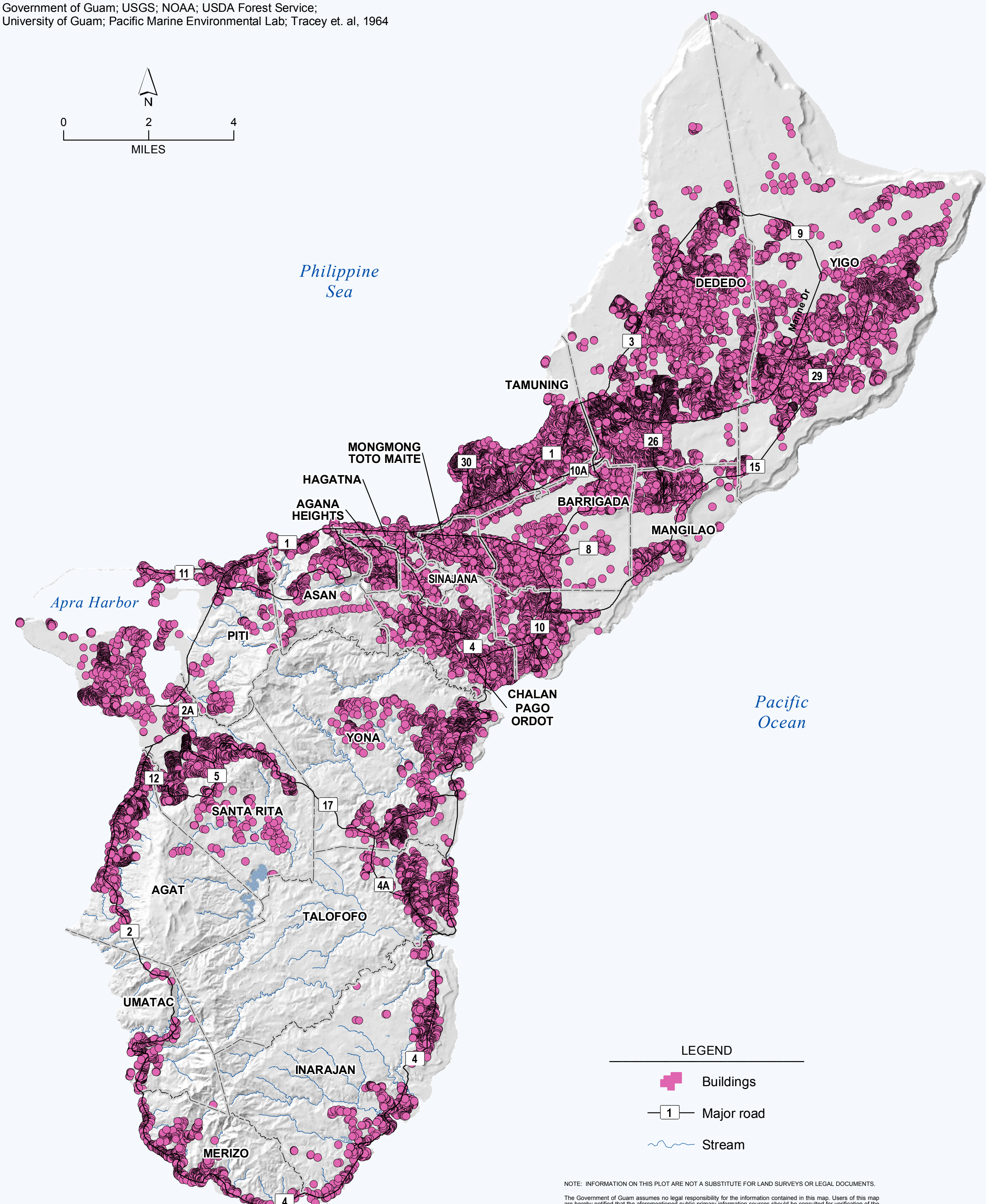

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Figure D-12
General building stock

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Data sources:
Government of Guam; USGS; NOAA; USDA Forest Service;
University of Guam; Pacific Marine Environmental Lab; Tracey et. al, 1964

Note:
To account for the uncertainty in the location of surface fault traces and the width of the deformation zone, the zones that are considered to have a potentially high surface faulting hazard encompass a 0.18-mile radial buffer (984.25 feet.) surrounding the faults.

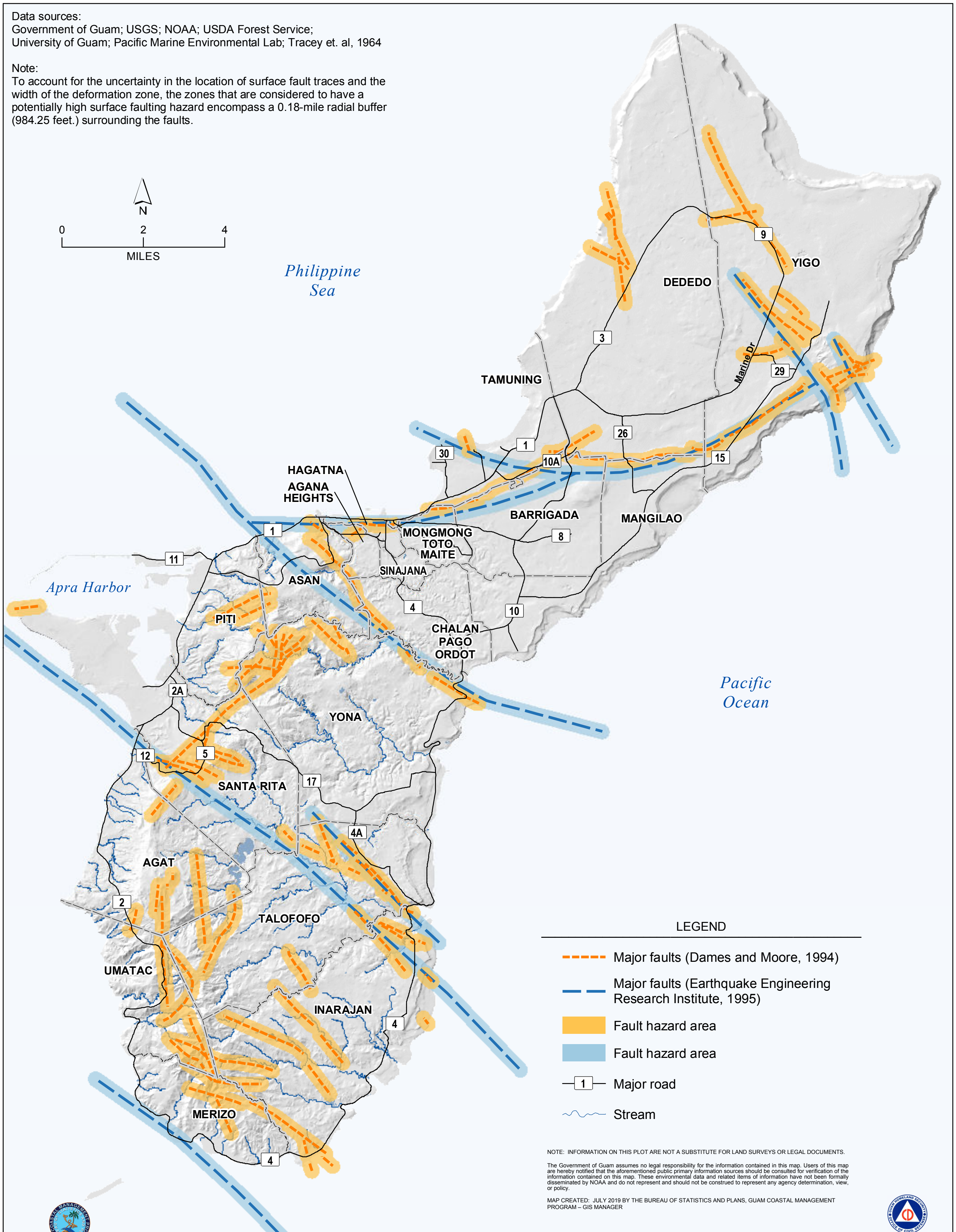

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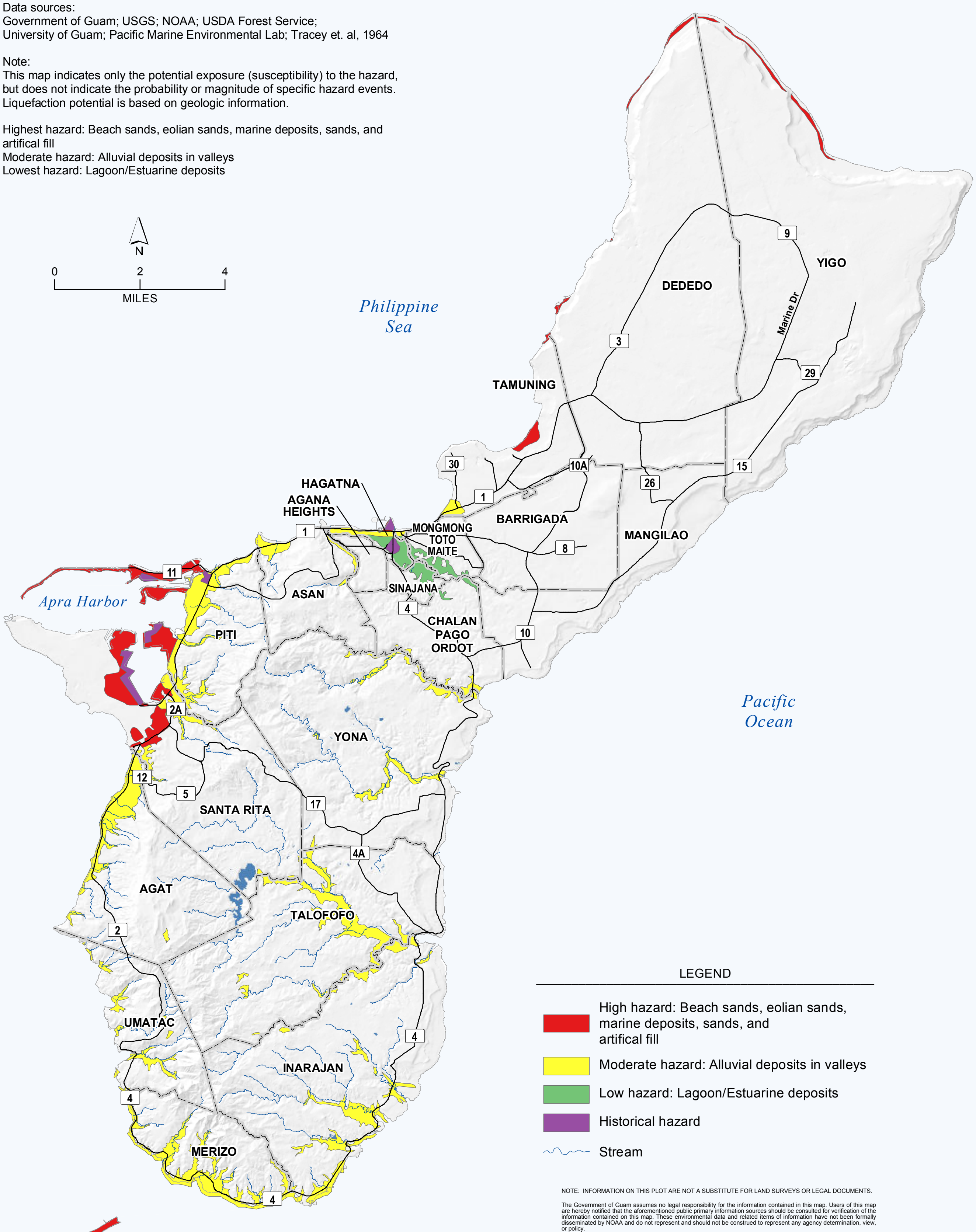
Figure D-13
Fault susceptibility

Data sources:
Government of Guam; USGS; NOAA; USDA Forest Service;
University of Guam; Pacific Marine Environmental Lab; Tracey et. al, 1964

Note:
This map indicates only the potential exposure (susceptibility) to the hazard, but does not indicate the probability or magnitude of specific hazard events. Liquefaction potential is based on geologic information.

Highest hazard: Beach sands, eolian sands, marine deposits, sands, and artifical fill
Moderate hazard: Alluvial deposits in valleys
Lowest hazard: Lagoon/Estuarine deposits



LEGEND

(red)	High hazard: Beach sands, eolian sands, marine deposits, sands, and artifical fill
(yellow)	Moderate hazard: Alluvial deposits in valleys
(green)	Low hazard: Lagoon/Estuarine deposits
(purple)	Historical hazard
(blue line)	Stream

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Figure D-14
Liquefaction hazard area

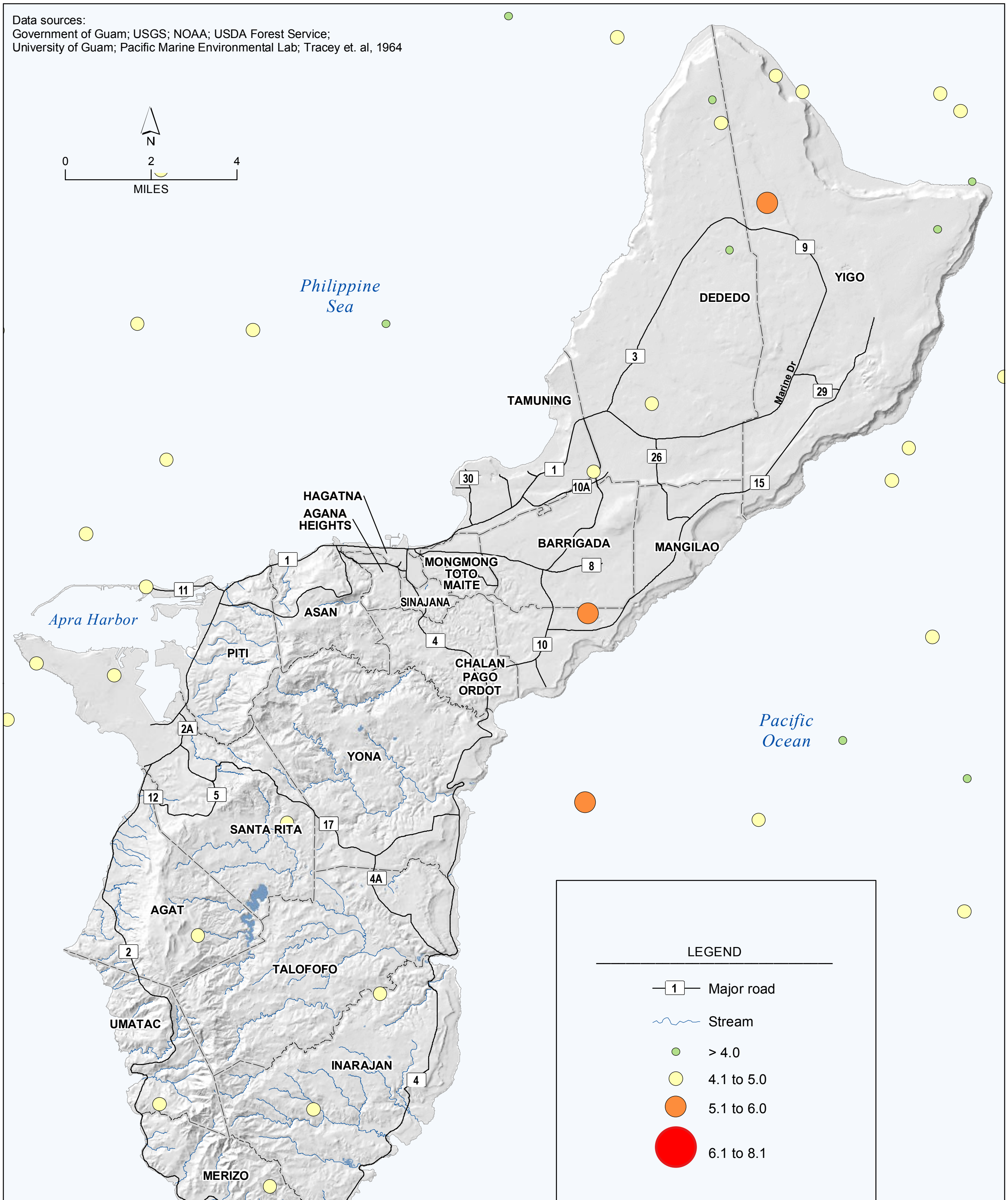

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Figure D-15
Local historical seismicity, 1900-2013

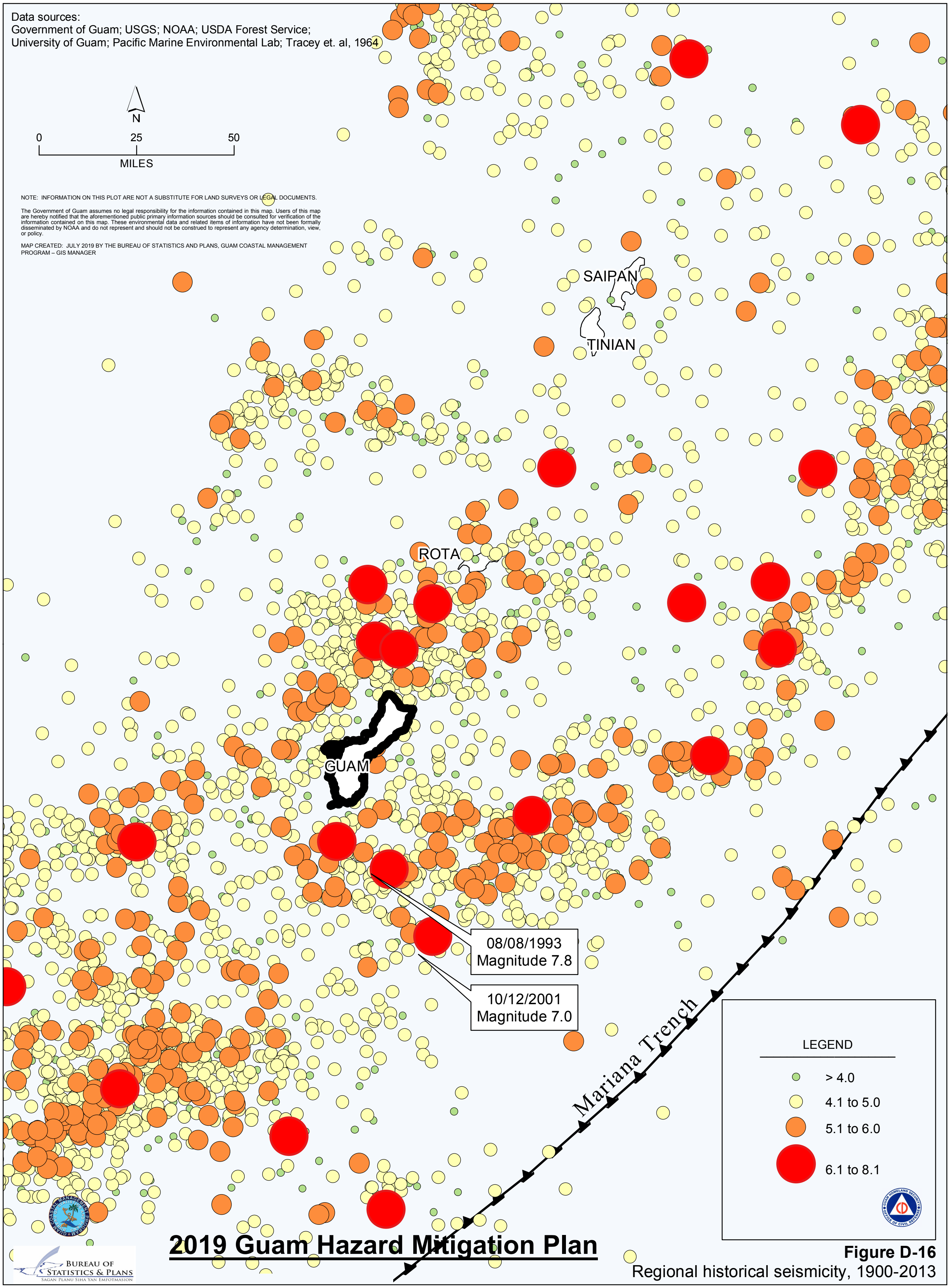

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Figure D-16
Regional historical seismicity, 1900-2013

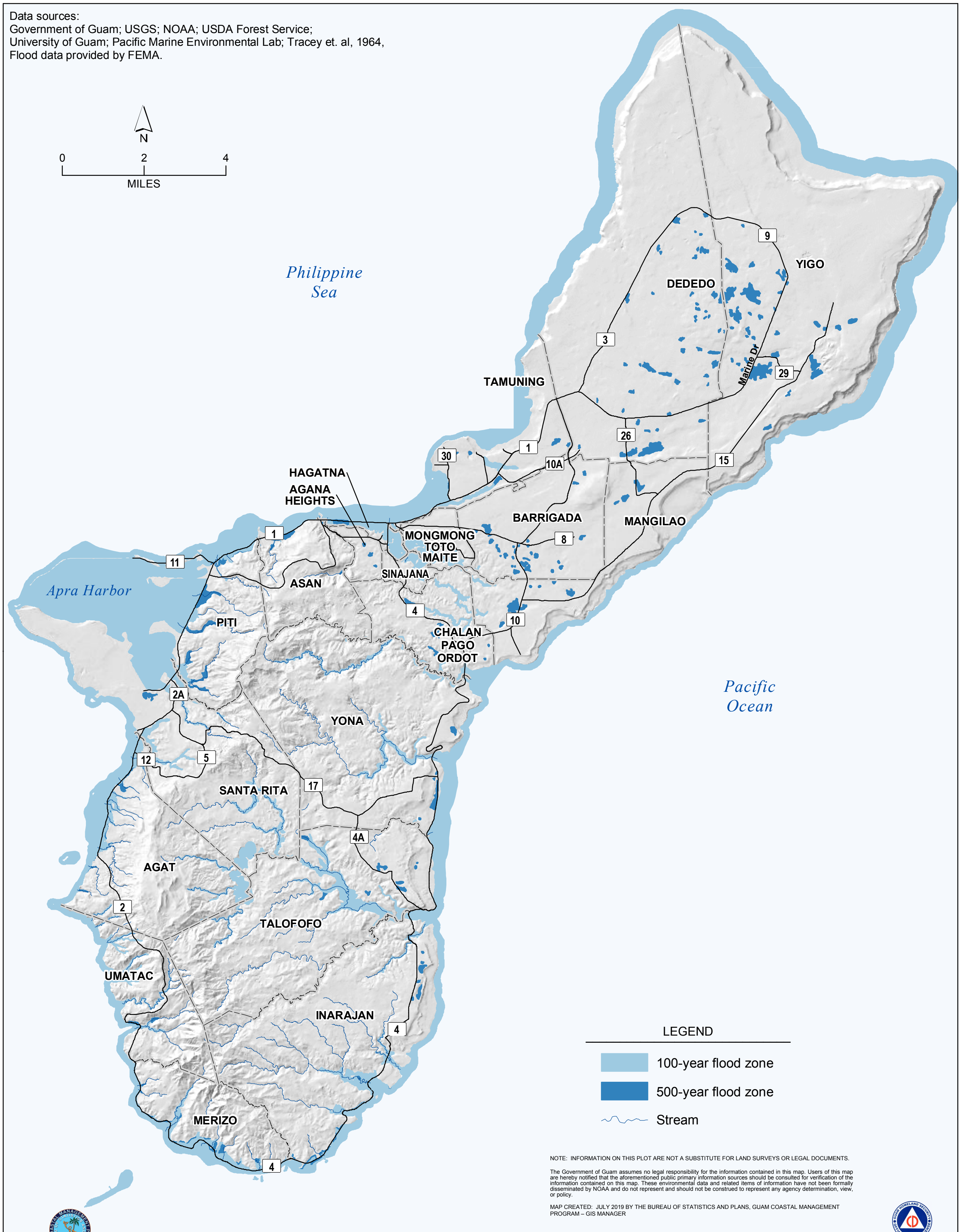

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Figure D-17
Special flood hazard area

Data sources:
Government of Guam; USGS; NOAA; USDA Forest Service;
University of Guam; Pacific Marine Environmental Lab; Tracey et. al, 1964

Note:
This map indicates only the potential exposure (susceptibility) to the hazard, but does not indicate the probability or magnitude of specific hazard events. The hazard area is a 1-mile radius of sewage treatment outfall locations.

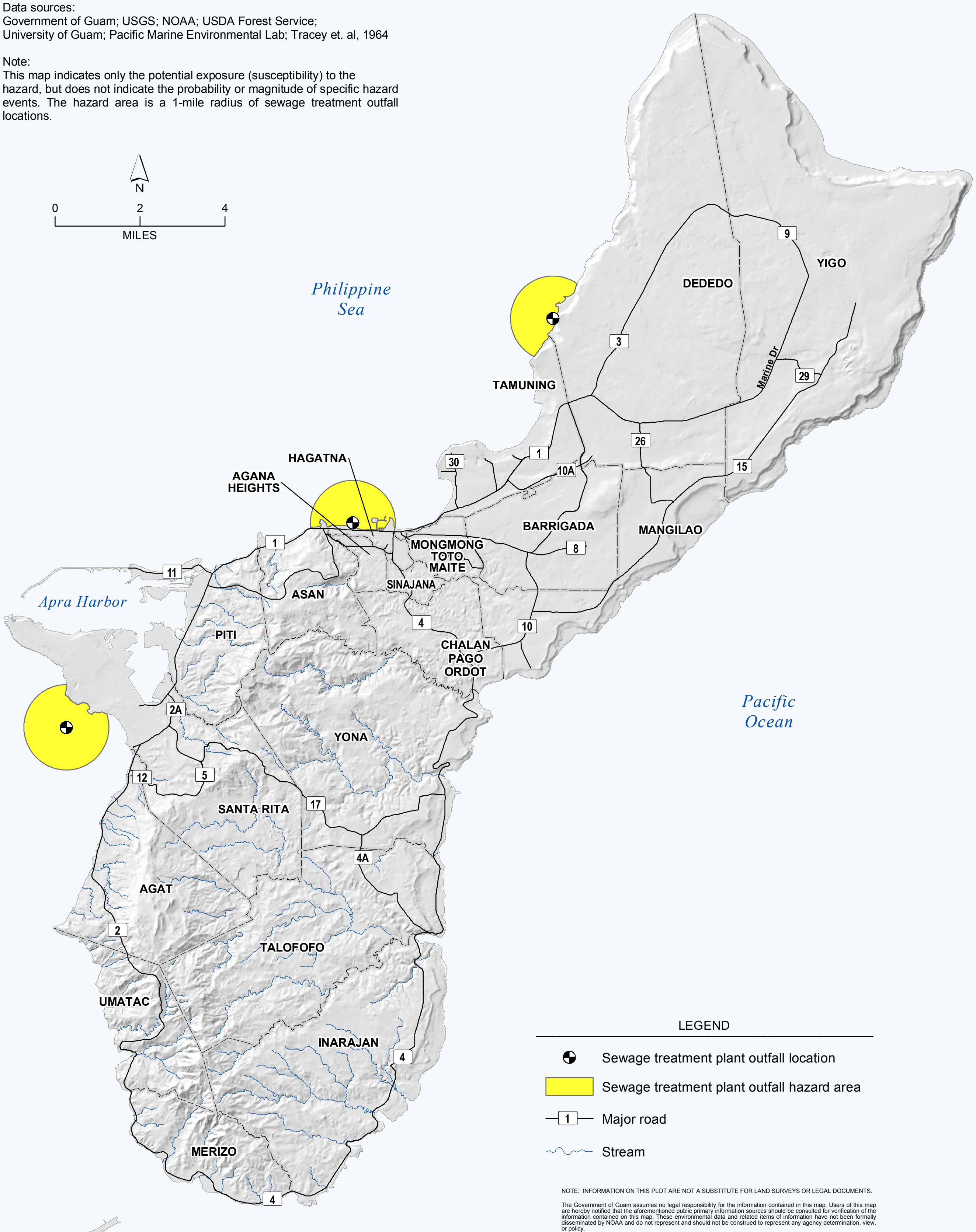

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Figure D-18
Sewage discharge susceptibility

Data sources:
Government of Guam; USGS; NOAA; USDA Forest Service;
University of Guam; Pacific Marine Environmental Lab; Tracey et. al, 1964

Note:
This map indicates only the potential exposure (susceptibility) to the hazard, but does not indicate the probability or magnitude of specific hazard events. The hazard area is a 1-mile radius of permitted facility locations.

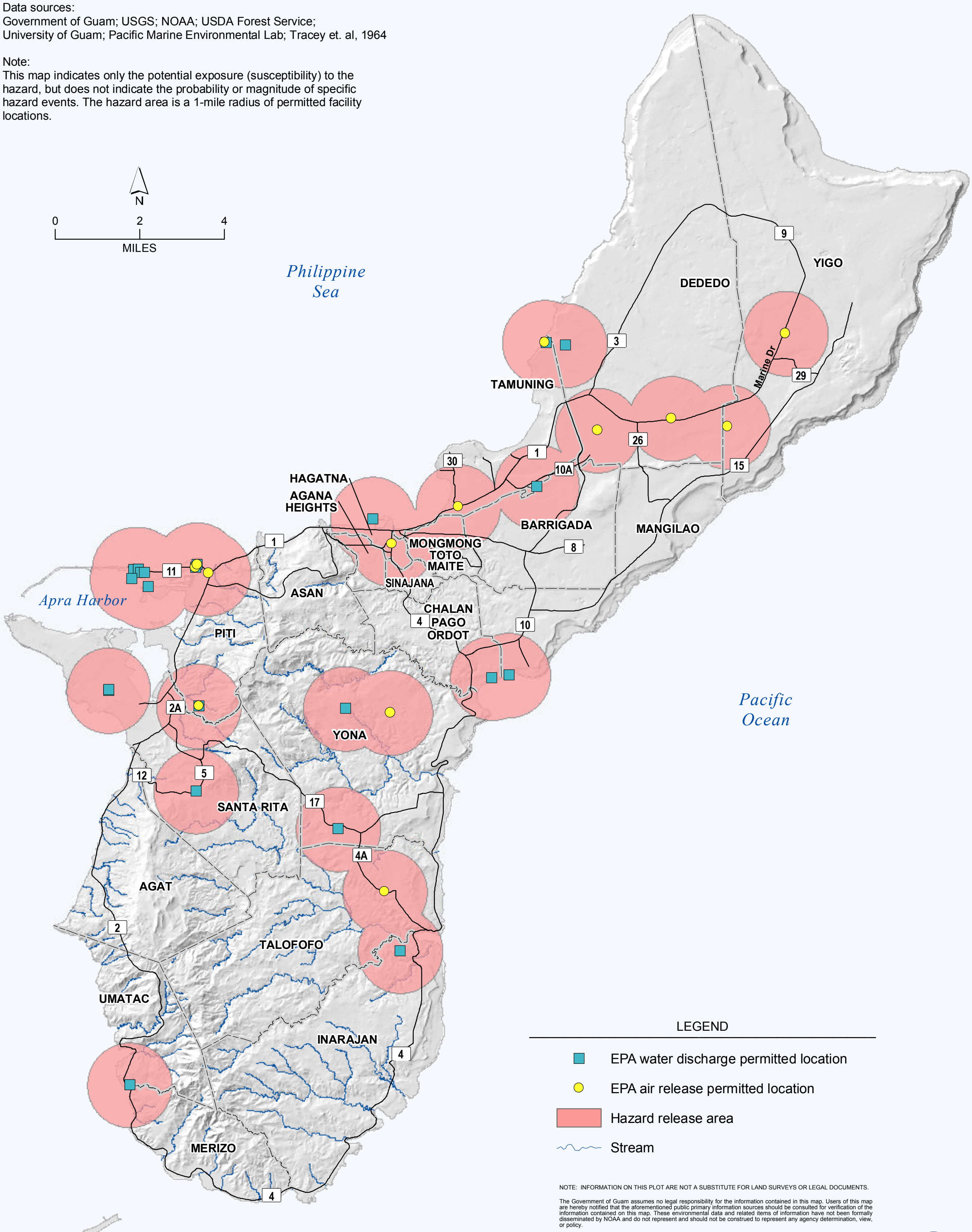

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Figure D-19
Air and water permitted facilities

Data sources:
Government of Guam; USGS; NOAA; USDA Forest Service;
University of Guam; Pacific Marine Environmental Lab; Tracey et. al, 1964

Note:
This map indicates only the potential exposure (susceptibility) to the hazard, but does not indicate the probability or magnitude of specific hazard events. The hazard area is a 1-mile buffer around hardfill facilities.

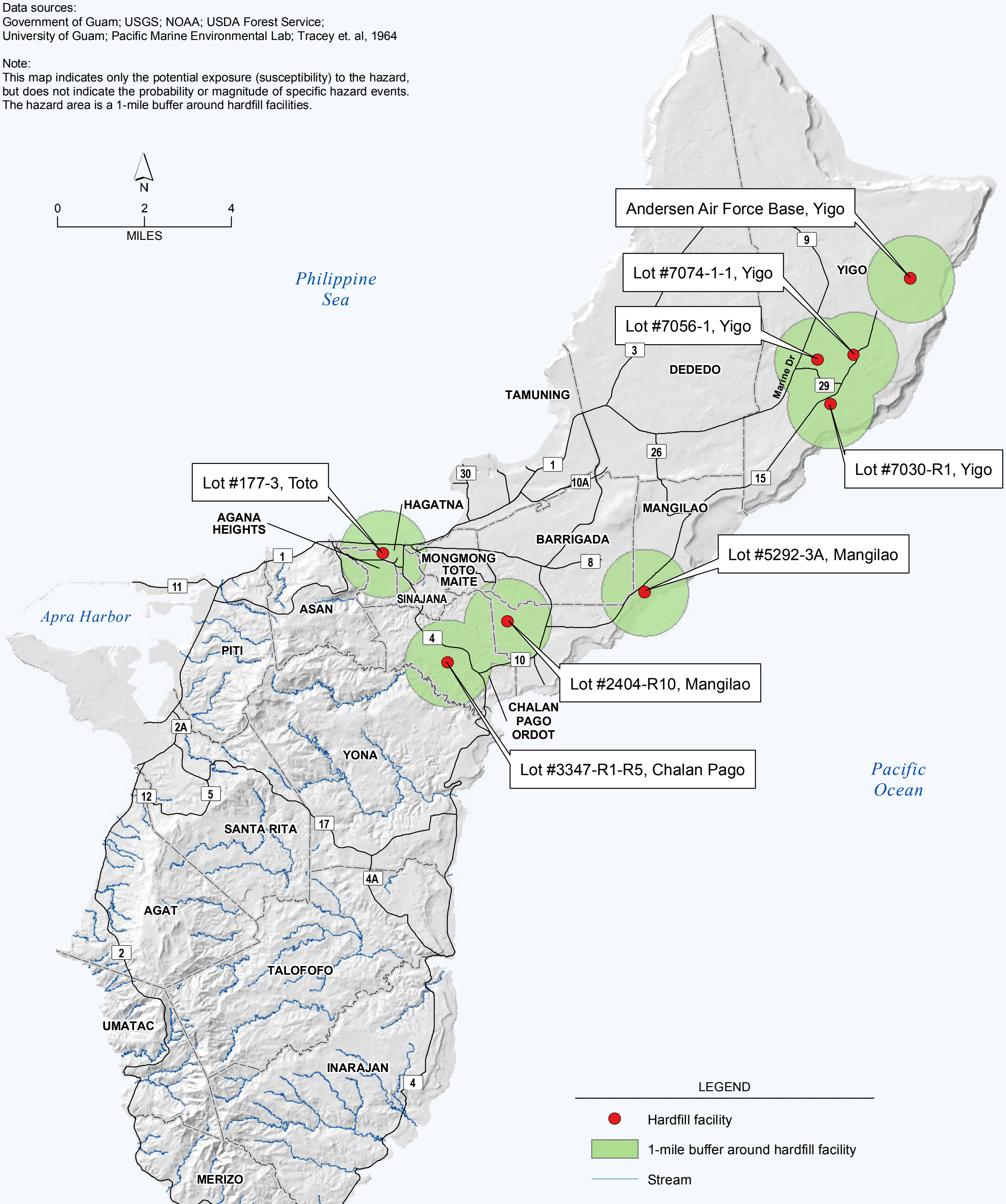

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Figure D-20
Hardfill site hazard area

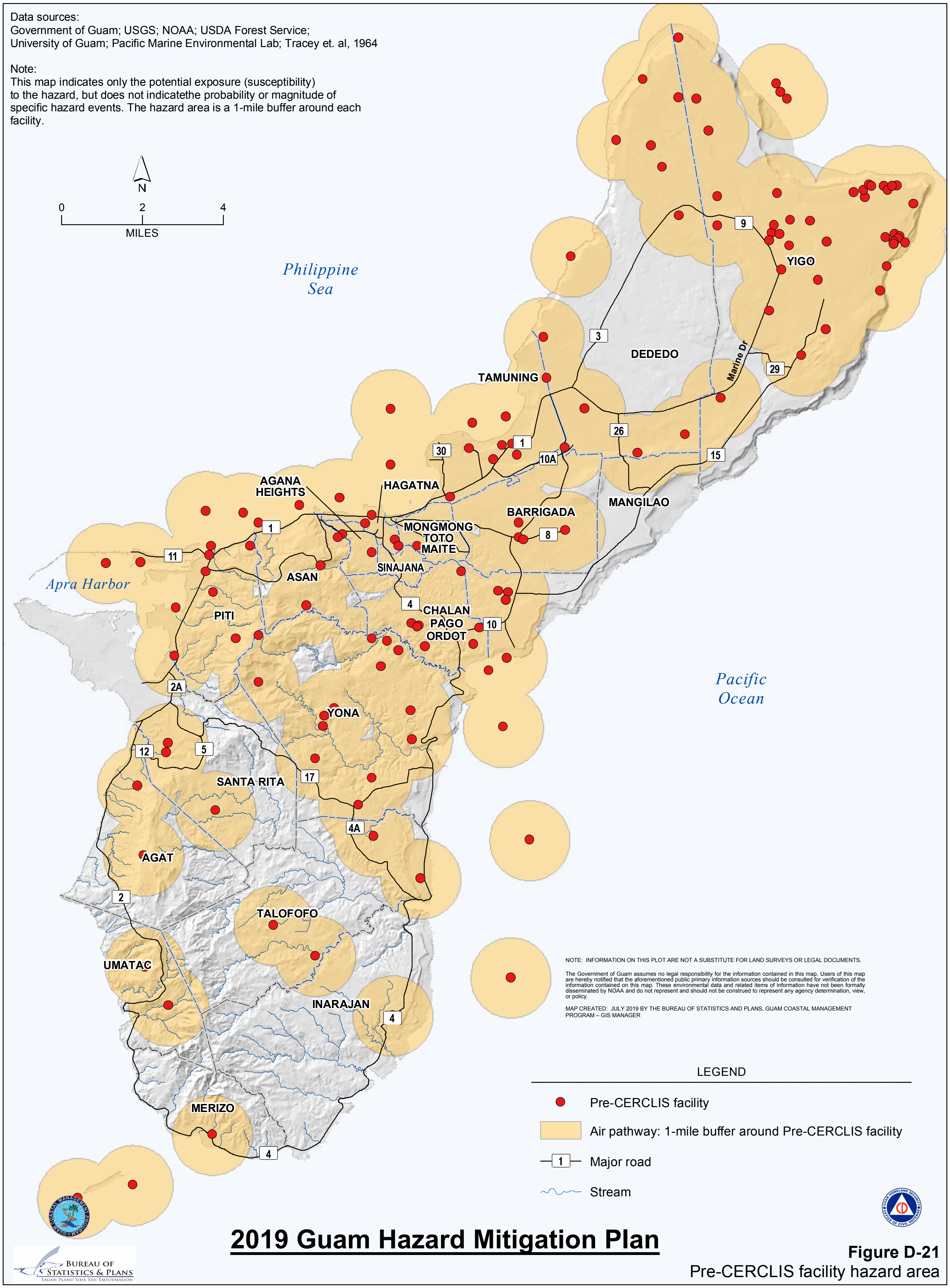

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Figure D-21
Pre-CERCLIS facility hazard area

Data sources:
Government of Guam; USGS; NOAA; USDA Forest Service;
University of Guam; Pacific Marine Environmental Lab; Tracey et. al, 1964

Note:
This map indicates only the potential exposure (susceptibility) to the hazard, but does not indicate the probability or magnitude of specific hazard events. This is a generalized description for areas that are naturally more susceptible to severe winds.

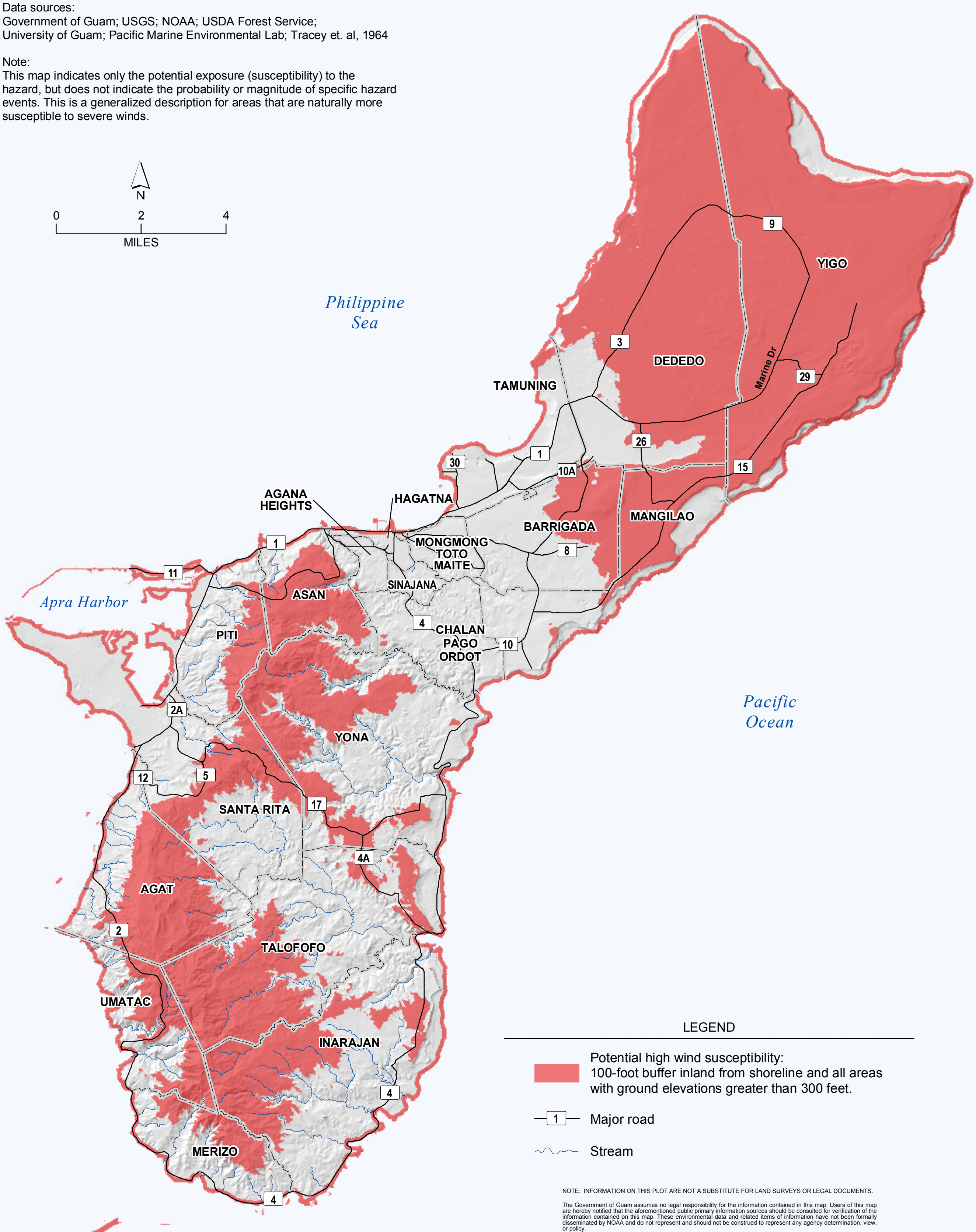

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Figure D-22
Severe wind hazard area

Data sources:
Government of Guam; USGS; NOAA; USDA Forest Service;
University of Guam; Pacific Marine Environmental Lab; Tracey et. al, 1964

Note:
This map indicates only the potential exposure (susceptibility) to the hazard, but does not indicate the probability or magnitude of specific hazard events. Dames and Moore (1994) defines the susceptibility of an area to landslide hazards based on geology. That analysis has been modified to incorporate slope angles. All slopes with an angle of 30 percent or more that were not already rated by Dames and Moore as having a high potential were rated to have a moderate to high potential for a landslide to occur. All slopes that have less than a 5 percent slope were rated to have a low potential regardless of the geologic deposits present.

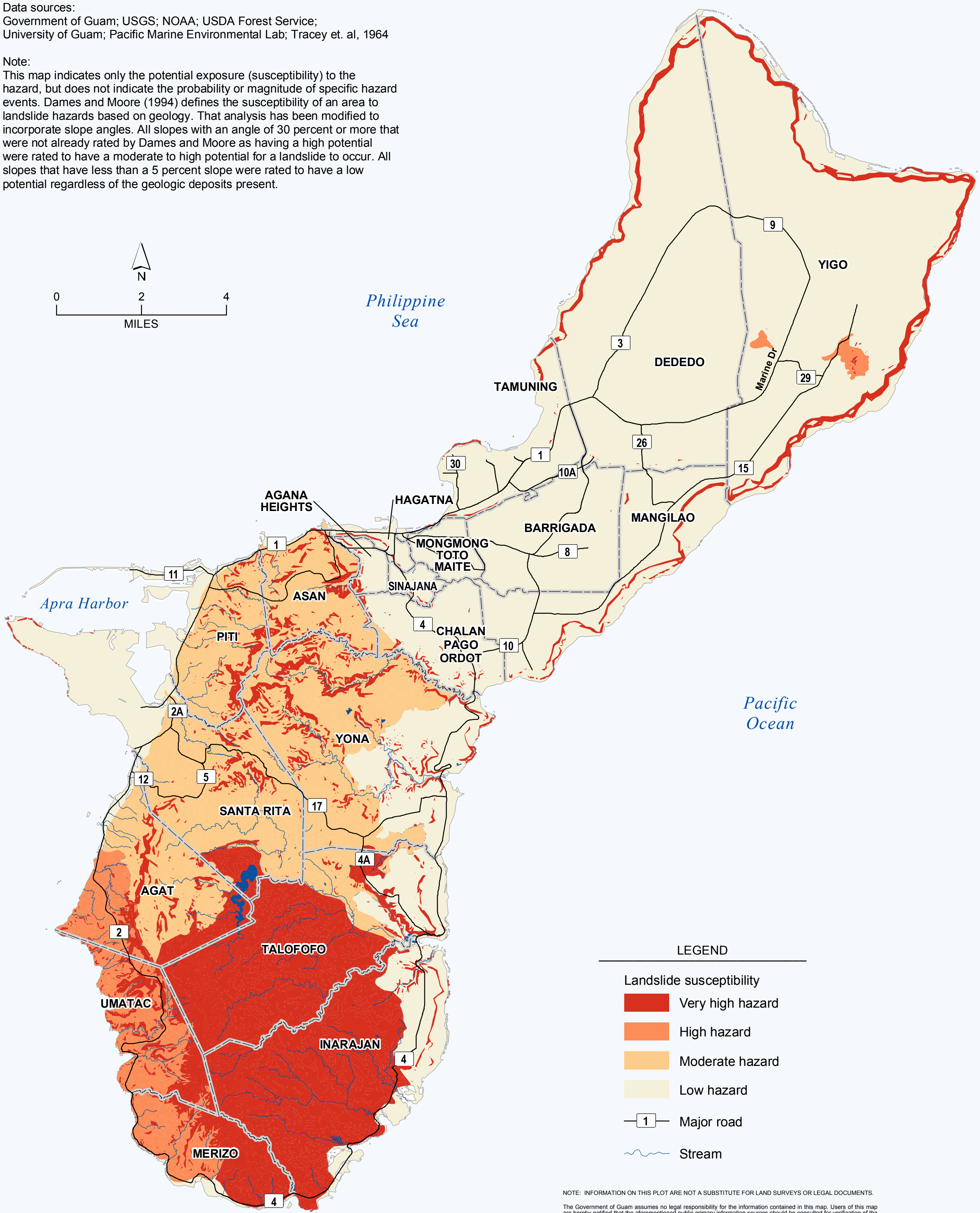

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Figure D-23
Landslide susceptibility

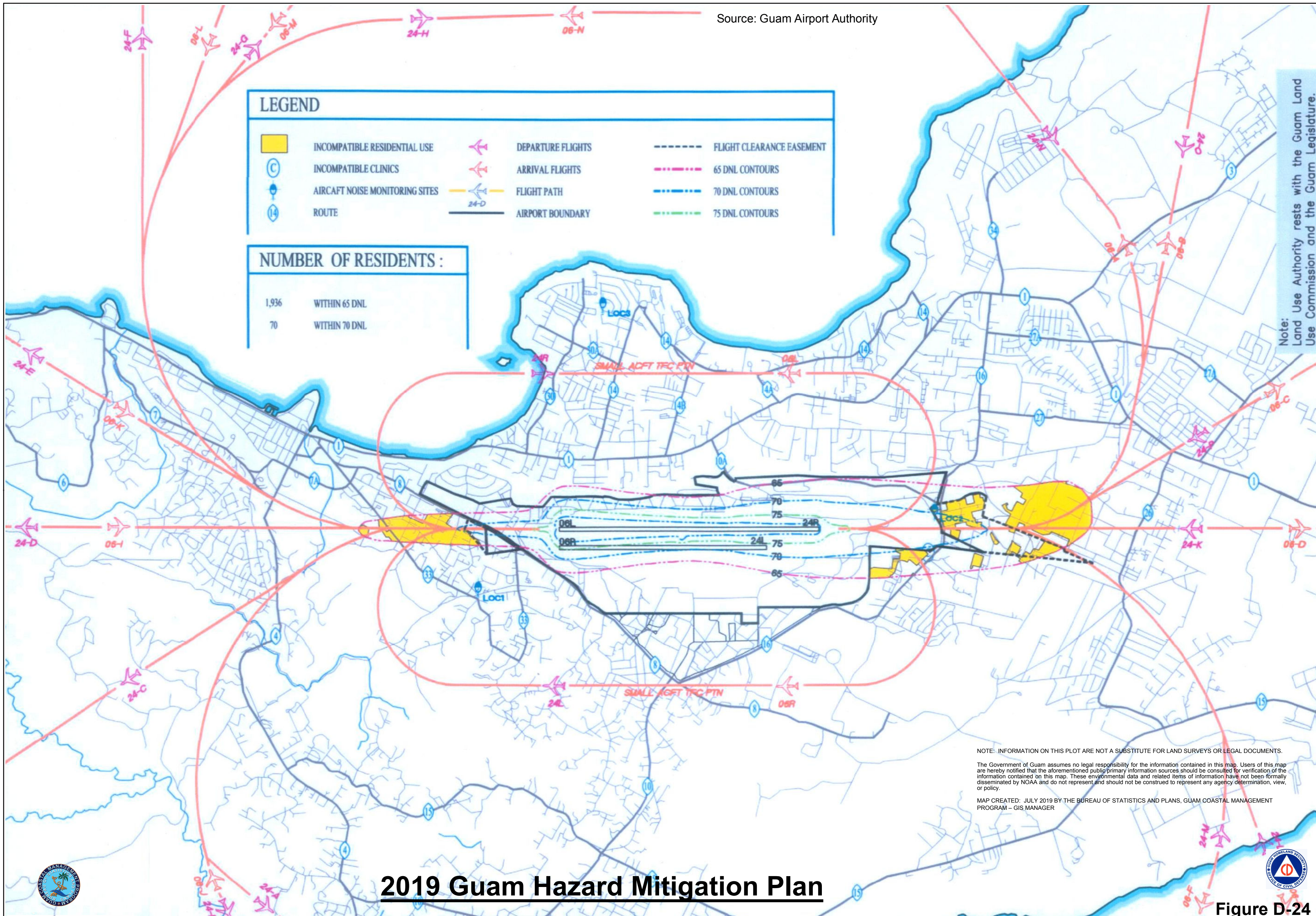

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Figure D-24
Guam International Airport and flight paths

Data sources:
Government of Guam; USGS; NOAA; USDA Forest Service;
University of Guam; Pacific Marine Environmental Lab; Tracey et. al, 1964

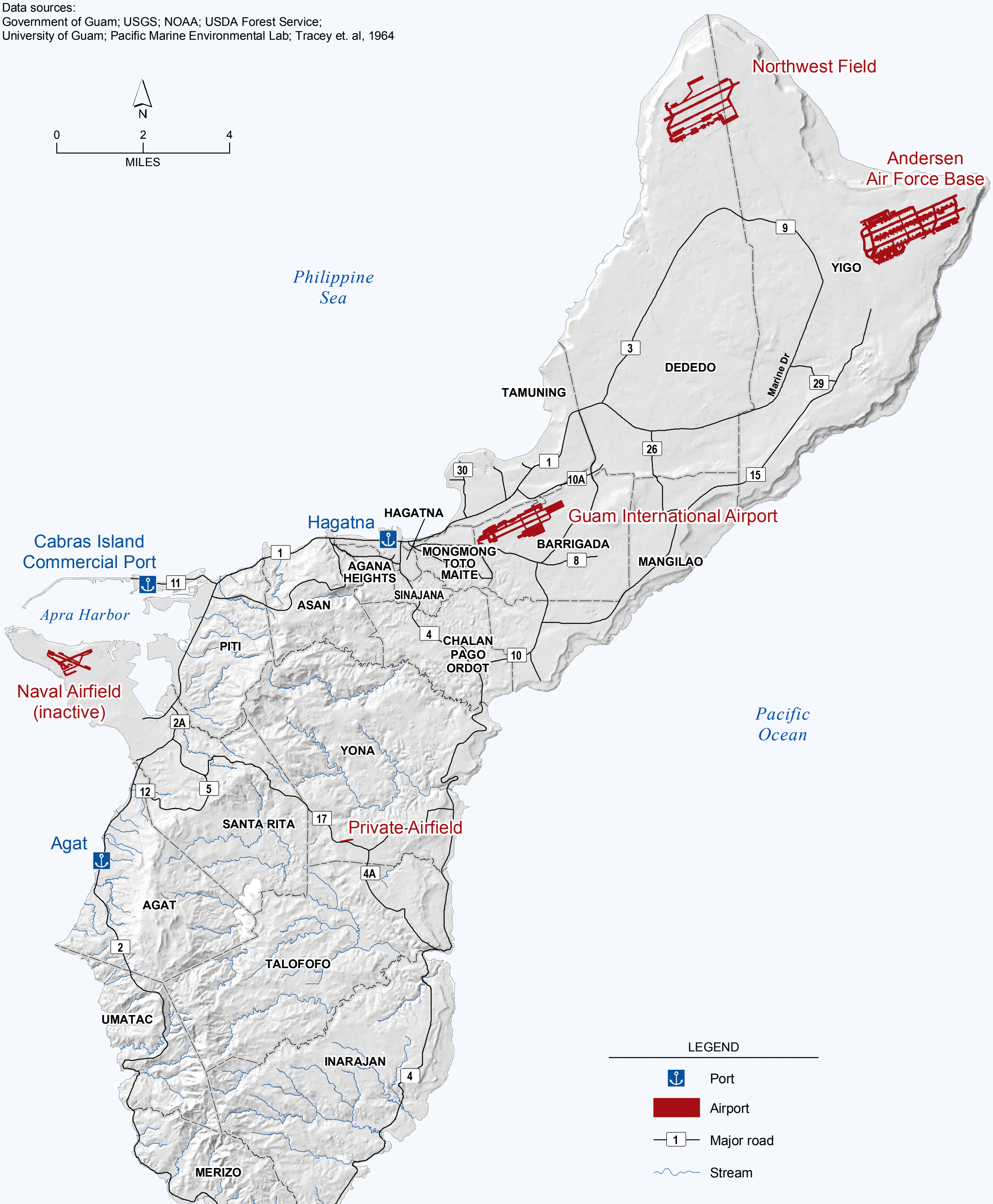

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Figure D-25
Air and sea ports

Data sources:
Government of Guam; USGS; NOAA; USDA Forest Service;
University of Guam; Pacific Marine Environmental Lab; Tracey et. al, 1964

Note:
This map indicates only the potential exposure (susceptibility) to the hazard, but does not indicate the probability or magnitude of specific hazard events. The tsunami inundation shown is based on the Guam Tsunami Inundation Areas Study from the National Oceanic and Atmospheric Administration (NOAA) and the Pacific Marine Environmental Lab (October 2009). Also incuded are low-lying areas up to 16.4 feet.

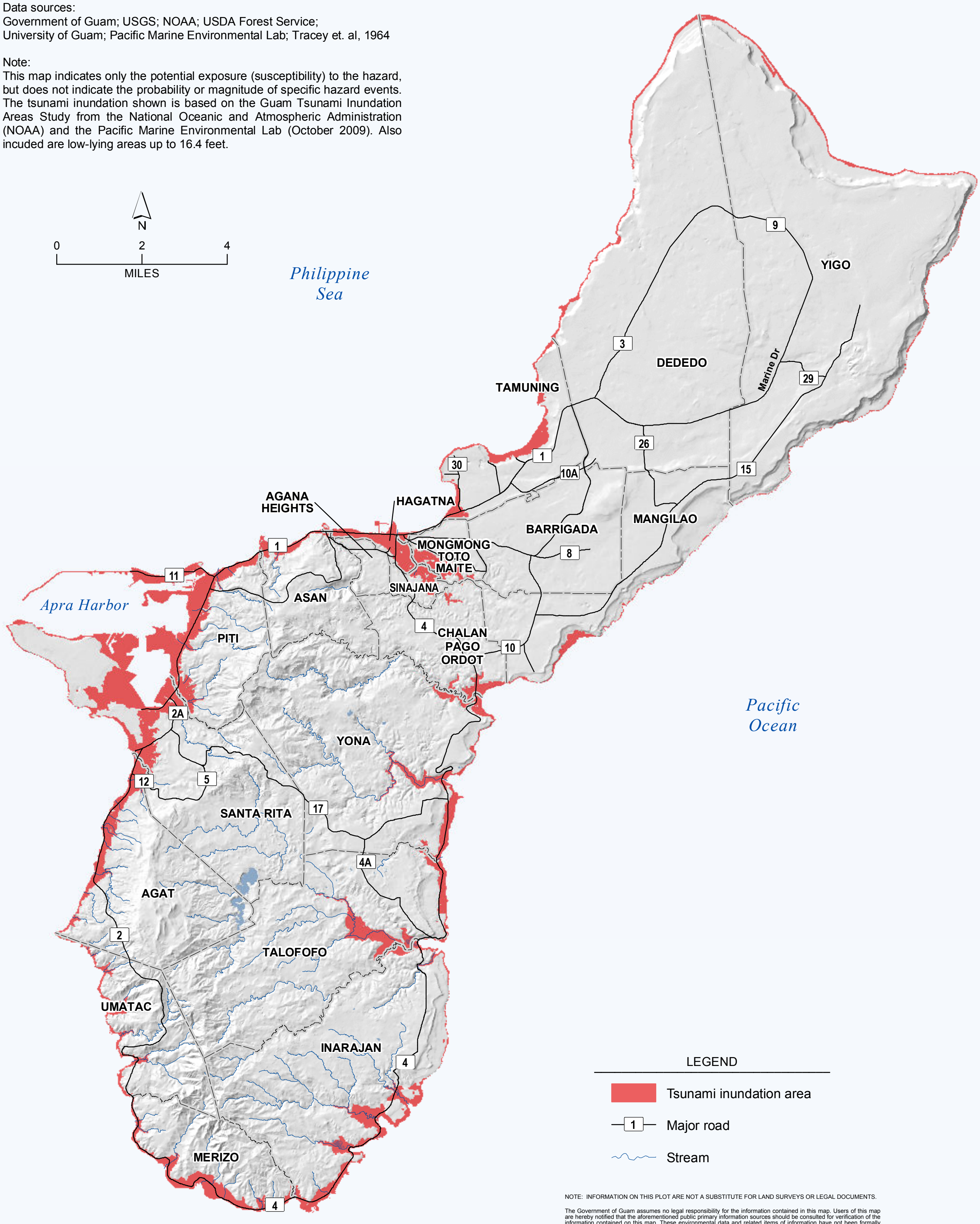

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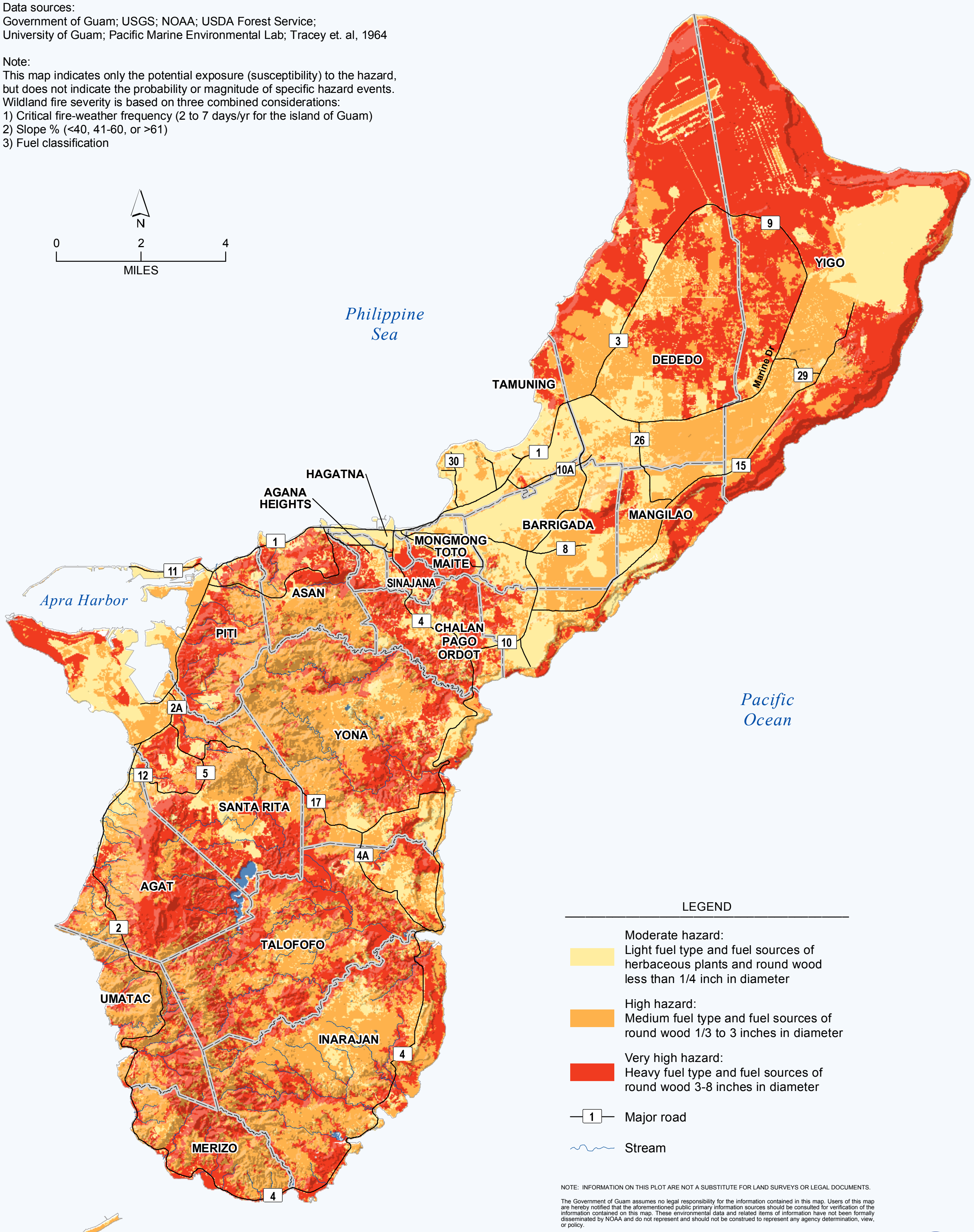
Figure D-26
Tsunami inundation hazard area

Data sources:
Government of Guam; USGS; NOAA; USDA Forest Service;
University of Guam; Pacific Marine Environmental Lab; Tracey et. al, 1964

Note:
This map indicates only the potential exposure (susceptibility) to the hazard, but does not indicate the probability or magnitude of specific hazard events.
Wildland fire severity is based on three combined considerations:
1) Critical fire-weather frequency (2 to 7 days/yr for the island of Guam)
2) Slope % (<40, 41-60, or >61)
3) Fuel classification



NOTE: INFORMATION ON THIS PLOT ARE NOT A SUBSTITUTE FOR LAND SURVEYS OR LEGAL DOCUMENTS.

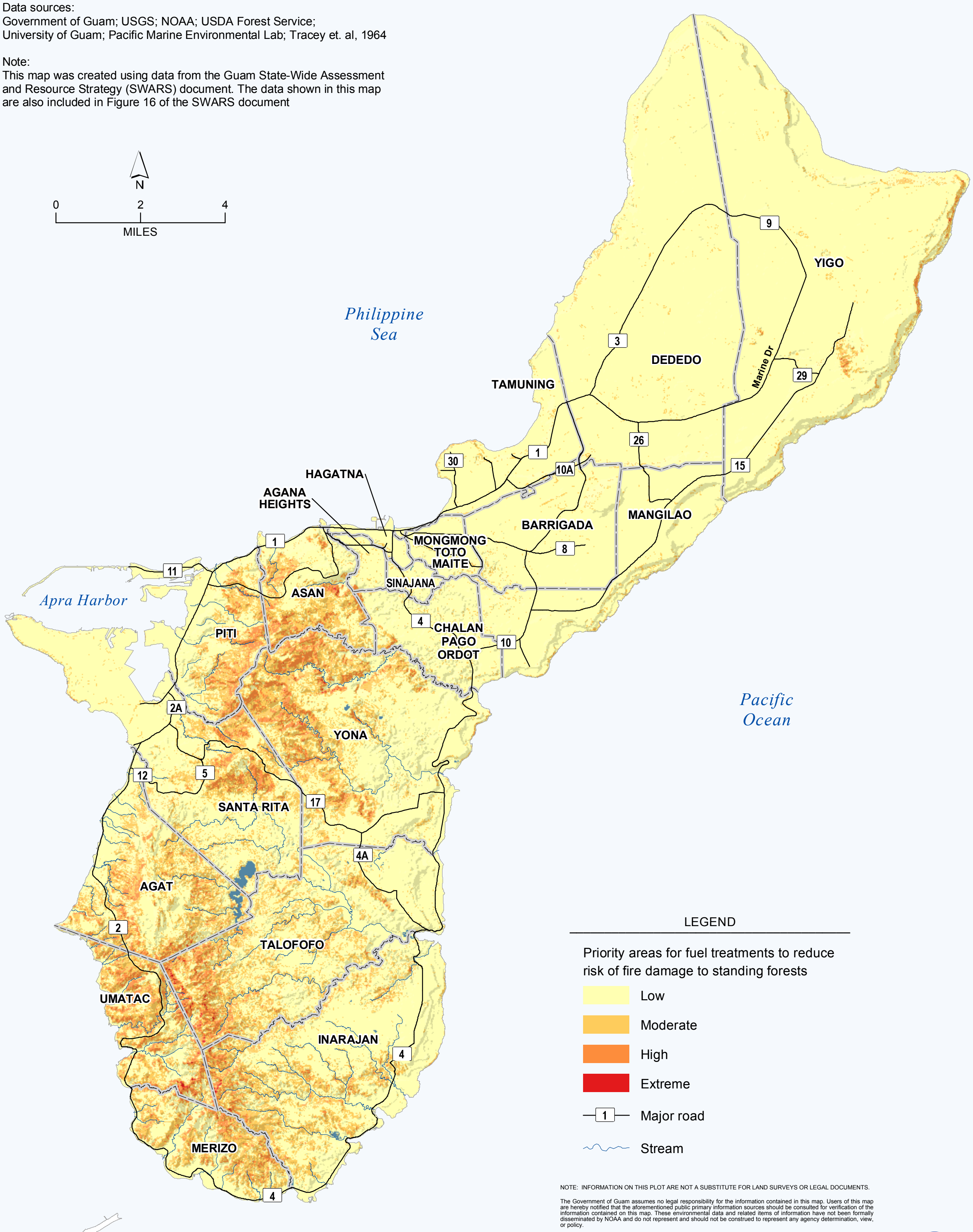
MAP CREATED: JULY 2019 BY THE BUREAU OF STATISTICS AND PLANS, GUAM COASTAL MANAGEMENT PROGRAM – GIS MANAGER

Bureau of Statistics & Plans
Sagan Planu Siha Yan Emfotmasion

Figure D-27
Wildland fire hazard area

Data sources:
Government of Guam; USGS; NOAA; USDA Forest Service;
University of Guam; Pacific Marine Environmental Lab; Tracey et. al, 1964

Note:
This map was created using data from the Guam State-Wide Assessment and Resource Strategy (SWARS) document. The data shown in this map are also included in Figure 16 of the SWARS document



NOTE: INFORMATION ON THIS PLOT ARE NOT A SUBSTITUTE FOR LAND SURVEYS OR LEGAL DOCUMENTS.

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2019 Guam Hazard Mitigation Plan

Figure D-28
Priority areas for fuel treatments

Appendix E
Essential Facilities, Major Utilities, and Transportation Systems

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Table E-1 Essential Facilities

Category	Facility Name	Village
Fire Stations	Agat New Fire Rescue Station	Agat
	Agat Fire Station #5	Agat
	Agat Harbor Fire Rescue	Agat
	Barrigada Fire Station #3	Barrigada
	911 Fire Dispatch	Barrigada
	Fire Rescue Base #1	Barrigada
	Guam International Airport, Aircraft Fire Rescue Station	Barrigada
	Astumbo Fire Station #12	Dededo
	Dededo Fire Station #4	Dededo
	Inarajan Fire Station #6	Inarajan
	Piti Fire Station #7	Piti
	Sinajana Fire #2	Sinajana
	Talofofo Fire Station #11	Talofofo
	Tamuning/Tumon Fire Station #1	Tamuning/Tumon
	Umatac Fire Station #8	Umatac
	Yigo Fire Station #10	Yigo
	Yona Fire Station #9	Yona
Police Stations	Agat Police Precinct Command	Agat
	Southern Police Precinct Command	Agat
	Agat Senior Citizen Center	Agat
	Dededo Police Precinct Command	Dededo
	Dededo Senior Citizen Center	Dededo
	Astumbo Senior Citizen Center	Dededo
	Hagatna Police Precinct Command	Hagatna

Table E-1 Essential Facilities

Category	Facility Name	Village
Police Stations (cont'd.)	Tamuning/Tumon Police Koban	Tamuning/Tumon
	Tumon Police Koban	Tamuning/Tumon
	Tumon/Tamuning/Tumon Precinct Command	Tamuning/Tumon
	Guam Police Department Headquarters	Mongmong-Toto-Maite
Senior Centers	Agana Heights Senior Citizens Center*	Agana Heights
	Agat Senior Citizens Center*	Astumbo, Dededo
	Astumbo Senior Citizens Center*	Agat
	Dededo Senior Citizens Center*	Dededo
	The Adult Day Care*	Dededo
	Inarajan Senior Citizens Center	Inarajan
	Mangilao Senior Citizens Center	Mangilao
	Merizo Senior Citizens Center	Merizo
	Santa Rita Senior Citizens Center	Santa Rita
	Sinajana Senior Citizens Center*	Sinajana
	Tamuning/Tumon Senior Citizens Center	Tamuning/Tumon
	GUMA Trankilidat Senior Citizens Home	Tamuning/Tumon
	Yigo Senior Citizens Center*	Yigo
	Yona Senior Citizens Center	Yona
Community Centers	Agana Heights Community Center	Agana Heights
	Agat Community Center	Agat
	Asan Community Center	Asan
	Barrigada Community Center	Barrigada
	Chalan Pago Community Center	Chalan Pago
	Dededo Community Center	Dededo

Table E-1 Essential Facilities

Category	Facility Name	Village
	Lagu Resource Center (Youth Center)	Dededo
	Mangilao Community Center	Mangilao
	Merizo Community Center	Merizo
	Merizo Youth Center	Merizo
	Mongmong-Toto-Maite Community Center	Mongmong-Toto-Maite
Community Centers (cont'd.)	Santa Rita Community Center	Santa Rita
	Sinajana Community Center	Sinajana
	Tamuning/Tumon Community Center	Tamuning/Tumon
	Yona Community Center	Yona
Historic Sites	Padre Palomo Historic Site	Hagatna
	Plaza De Espana Historic Site	Hagatna
	San Antonio Historic Bridge	Hagatna
	Fort Santa Agueda Historic Site	Hagatna
	Government Hill	Hagatna
	Japanese Historic Cave	Hagatna
	Latte Stone Historic Park	Hagatna
	Atantano Historic Shrine	Piti
	Fort San Jose	Umatac
	Umatac Bay Historic Park	Umatac
	San Dionisio Historic Church Ruins	Umatac
	South Pacific Memorial Park	Yigo
Cemeteries and Burial Grounds	Naval Memorial Cemetery Park	Hagatna
	Inarajan Public Burial Ground	Inarajan
	Merizo Public Burial Ground	Merizo

Table E-1 Essential Facilities

Category	Facility Name	Village
	Guam Veterans Burial Ground	Piti
	Vicente A. Limtiaco Public Burial Ground	Piti
Parks, Preserves, and Beaches	Anae Island Territorial Park	Agat
	Nimitz Territorial Beach Park	Agat
	Hill 40	Agat
	Alutom Natural Preserve Island	Agat
	Yona Natural Preserve Island	Agat
	Agat Marina*	Agat
	Nimitz House	Asan
	Barrigada War Memorial Park	Barrigada
	Francisco Perez Beach Park	Chalan Pago-Ordot
	Central Park	Dededo
	Falcona Natural Preserve Beach	Dededo
	Buffer Territorial Strip Park	Dededo
	Agana Wetlands Park	Hagatna
	East Agana Beach	Hagatna
	West Agana Territorial Beach Park	Hagatna
	Skinner Plaza Territorial Park	Hagatna
	San Roman Hill Hilltriangle Park	Hagatna
	Adelup Territorial Park	Hagatna
	Marine Drive Territorial Strip Park	Hagatna
	Paseo De Susana Territorial Park	Hagatna
	G.D. Perez Marina*	Hagatna
	Saluglula Territorial Pool Park	Inarajan

Table E-1 Essential Facilities

Category	Facility Name	Village
	Talofofo Territorial Beach Park	Inarajan
	Asgon Natural Preserve Island	Inarajan
Parks, Preserves, and Beaches (cont'd.)	Gef Pago Cultural Village	Inarajan
	Guijen Natural Preserve Island	Inarajan
	Asiga Territorial Beach Park	Inarajan
	Iates Conservation Reserve	Mangilao
	Fadian Point Conservation Reserve	Mangilao
	Taguan Conservation Reserve	Mangilao
	Merizo Seashore Pier Park	Merizo
	Dano Seashore Park	Merizo
	Hoover Park	Piti
	Tepungan Territorial Beach Park	Piti
	Piti Bay Conservation Reserve	Piti
	Pedro Santos Park	Piti
	Luminao Reef Conservation Reserve	Piti
	Agana Spring Conservation Reserve	Sinajana
	Ipan Territorial Beach Park	Talofofo
	Asquiroga Territorial Cave Park	Talofofo
	Tinechong Conservation Reserve	Talofofo
	Chinese Park	Tamuning/Tumon
	Matapang Territorial Beach Park	Tamuning/Tumon
	Aputguan Territorial Beach Park	Tamuning/Tumon
	Puntan Dos Amantes Territorial Park	Tamuning/Tumon
	Tanguisson Territorial Beach Park	Tamuning/Tumon

Table E-1 Essential Facilities

Category	Facility Name	Village
Parks, Preserves, and Beaches (cont'd.)	Governor Joseph Flores-Ypao Territorial Beach Park	Tamuning/Tumon
	Tamuning/Tumon Natural Preserve Lot	Tamuning/Tumon
	Alupat Natural Preserve Island	Tamuning/Tumon
	Fort Nuestra De La Soledad	Umatac
	Fort Santo Angel	Umatac
	Anao Natural Preserve Lot	Yigo
	Lujuna Conservation Reserve	Yigo
	Tagachang Territorial Beach Park	Yona
	Togcha Beach Conservation Reserve	Yona
Recreation Facilities	Agana Heights Baseball Field	Agana Heights
	Agat Baseball Field	Agat
	Agat Small Boat Marina	Agat
	Maina Basketball Courts	Asan
	Tiyan North Softball Field	Barrigada
	Tiyan South Softball Field	Barrigada
	Tiyan Tennis Courts	Barrigada
	Adam William Leahy Sports Complex	Barrigada
	Jose Atoigue Baseball Field	Chalan Pago Ordot
	Dededo Robbie Webber Soccer Field	Dededo
	Dededo Baseball Field – Liguan	Dededo
	Dededo Baseball Field – Village	Dededo
	Dededo Baseball Field – Paradise Estate	Dededo

Table E-1 Essential Facilities

Category	Facility Name	Village
Recreation Facilities (cont'd.)	Wettengel Football Field	Dededo
	Guam Major League Baseball Field	Hagatna
	Jose Guerrero Baseball Field	Hagatna
	Hagatna Swimming Pool	Hagatna
	Hagatna Tennis Court	Hagatna
	Gregorio Periz Marina	Hagatna
	Inarajan Baseball Field	Inarajan
	Old Mangilao Baseball Field	Mangilao
	Mangilao Mayors Baseball Field	Mangilao
	George Washington Football and Track Field	Mangilao
	University of Guam Tennis Courts	Mangilao
	Soccer and Baseball Field	Mangilao
	Merizo Baseball Field	Merizo
	Mongmong-Toto-Maite Baseball Field	Mongmong-Toto-Maite
	Piti Baseball Field	Piti
	Joe Guzman Baseball Field	Santa Rita
	Sinajana Baseball Field	Sinajana
	Talofofo Baseball Field – East	Talofofo
	Talofofo Baseball Field – West	Talofofo
	Tamuning/Tumon Tennis Court	Tamuning/Tumon
	Greyhound Race Track	Tamuning/Tumon
	Tamuning/Tumon Baseball Field and Tennis Courts	Tamuning/Tumon
	Tumon Golf Driving Range	Tamuning/Tumon
	Umatac Baseball Field	Umatac

Table E-1 Essential Facilities

Category	Facility Name	Village
Recreation Facilities (cont'd.)	Yigo Baseball Field	Yigo
	Yona Baseball Field	Yona
	Baza Gardens Baseball Field	Yona
Governor's Complex	Government House	Hagatna
Government of Guam Administration, Agencies, Departments, and Offices	Agat Waste Transfer Station	Agat
	Department of Parks and Recreation Office	Agana Heights
	Department of Revenue and Taxation Office	Barrigada
	Guam Customs and Border Protection Office	Barrigada
	Guam Environmental Protection Agency – Main Office	Barrigada
	Guam Environmental Protection Agency Office	Barrigada
	GEPA Laboratory Offices	Barrigada
	Department of Integrated Services for Individuals with Disabilities Office	Barrigada
	Department of Military Affairs - Guam National Guard	Barrigada
	Guam Public Library System Office	Chalan Pago-Ordot
	Ordot Landfill	Chalan Pago-Ordot
	Commission on Decolonization, Bureau of Budget and Management Research, Bureau of Statistics and Plans, Chamarro Land Trust Commission, and Governor's Community Outreach Federal Programs Offices	Dededo
	Ancestral Lands Commission and Chamorro Land Trust Commission Offices	Dededo
	Guam Housing and Urban Renewal Authority GUMA San Jose Residential Center	Dededo
	Dededo Solid Waste Transfer Station	Dededo
	Department of Public Works Quarry Site	Dededo
	Guam Water Works Laboratory	Dededo
	Emergency Operation Center and Guam Homeland Security/Office of Civil Defense	Hagatna

Table E-1 Essential Facilities

Category	Facility Name	Village
Government of Guam Administration, Agencies, Departments, and Offices (cont'd.)	Chamorro Village	Hagatna
	Public Defender's Office	Hagatna
	Governor Ricardo J. Bordallo Complex	Hagatna
	Guam Fire Department Headquarters	Hagatna
	Public Auditor's Office	Hagatna
	Guam Legislature	Hagatna
	Superior Court of Guam	Hagatna
	Guam Public School System Office	Hagatna
	Office of the Attorney General	Hagatna
	Department of Administration Office	Hagatna
	Department of Labor Office	Hagatna
	Department of Vocational Rehabilitation Office	Hagatna
	Guam Council on the Arts and Humanities Agency Office	Hagatna
	Guam Mass Transit Authority Office	Hagatna
	Adult Correctional Facility	Mangilao
	Youth Correctional Facility	Mangilao
	Department of Public Health and Social Services Office	Mangilao
	Department of Youth Affairs Office	Mangilao
	Department of Agriculture Office	Mangilao
	Guam Developmental Disabilities Council Office	Mangilao
	Government of Guam Retirement Fund Office	Mongmong-Toto-Maite
	General Services Administration Office and Warehouse	Piti
	Port Authority of Guam Office Building	Piti

Table E-1 Essential Facilities

Category	Facility Name	Village
Government of Guam Administration, Agencies, Departments, and Offices (cont'd.)	Port Authority of Guam Security Building	Piti
	Guam Contractors License Board and Department of Public Works Office	Piti
	Guam Energy Office	Piti
	Guam Waterworks Authority Office	Piti
	Guam Public School System Warehouse	Piti
	Guam Housing and Urban Renewal Authority Office	Sinajana
	Guam Economic Development and Commerce Authority Office	Tamuning/Tumon
	Department of Land Management Office	Tamuning/Tumon
	Department of Public Works Compound	Tamuning/Tumon
	Guam Waterworks Authority Office	Tamuning/Tumon
	Pacific Energy Resource Center	Tamuning/Tumon
	Guam Fire Department Fleet Maintenance	Tamuning/Tumon
	Guam Power Authority Office	Tamuning/Tumon
	Guam Board of Accountancy Office	Tamuning/Tumon
	Guam Visitors Bureau Office	Tamuning/Tumon
	Department of Mental Health and Substance Abuse Office	Tamuning/Tumon
	Civil Service Commission Office	Tamuning/Tumon
	Veteran's Affairs Office	Tamuning/Tumon
	Office of the Medical Examiner	Tamuning/Tumon
	Guam Housing Corporation Office	Tamuning/Tumon
	Guam Appeals Board Office	Tamuning/Tumon

Table E-1 Essential Facilities

Category	Facility Name	Village
Libraries	Agat Public Library	Agat
	Barrigada Public Library	Barrigada
	Dededo Public Library	Dededo
	Nieves M. Flores Memorial Public Library	Hagatna
	Guam Territorial Law Library	Hagatna
	University of Guam Robert F. Kennedy Library	Mangilao
	University of Guam Micronesia Area Research Center	Mangilao
	Merizo Public Library	Merizo
	Yona Public Library	Yona
Mayors' Council of Guam	Mayors' Council Office	Hagatna
	Agana Heights Mayor's Office	Agana Heights
	Agat Mayor's Office	Agat
	Asan-Maina Mayor's Office	Asan
	Barrigada Mayor's Office	Barrigada
	Chalan Pago-Ordot Mayor's Office	Chalan Pago-Ordot
	Dededo Mayor's Office	Dededo
	Hagatna Mayor's Office	Hagatna
	Inarajan Mayor's Office	Inarajan
	Mangilao Mayor's Office	Mangilao
	Merizo Mayor's Office	Merizo
	Mongmong-Toto-Maite Mayor's Office	Mongmong-Toto-Maite
	Piti Mayor's Office	Piti
	Santa Rita Mayor's Office	Santa Rita

Table E-1 Essential Facilities

Category	Facility Name	Village
Mayors' Council of Guam (cont'd.)	Sinajana Mayor's Office	Sinajana
	Talofofo Mayor's Office	Talofofo
	Tamuning/Tumon Mayor's Office	Tamuning/Tumon
	Umatac Mayor's Office	Umatac
	Yigo Mayor's Office	Yigo
	Yona Mayor's Office	Yona
Health Care and Clinics	DMHSA Guma Ifil Office	Asan
	GMHA Skill Nursing Unit	Barrigada
	Northern Region Health Center	Dededo
	Inarajan Public Health Center	Inarajan
	Department of Mental Health and Substance Abuse Office	Tamuning/Tumon
Health Care and Clinics	Guam Memorial Hospital	Tamuning/Tumon
Public Schools	Agana Heights Elementary School	Agana Heights
	Oceanview Middle School	Agat
	Marcial Sablan Elementary School	Agat
	P.C. Lujan Elementary School	Barrigada
	L.P. Untalan Middle School	Barrigada
	Carbullido Elementary School	Barrigada
	Agueda Johnston Middle School	Chalan Pago-Ordot
	Ordot Chalan Pago Elementary School	Chalan Pago-Ordot
	Astumbo Middle School	Dededo
	Juan M. Guerrero Elementary School	Dededo
	Finegayan Elementary School	Dededo
	Liguan Elementary School	Dededo

Table E-1 Essential Facilities

Category	Facility Name	Village
Public Schools (cont'd.)	Wettengel Elementary School	Dededo
	Vicente S.A. Benavente Middle School	Dededo
	Maria Ulloa Elementary School	Dededo
	Astumbo Elementary School	Dededo
	Ukudu High School	Dededo
	Inarajan Elementary School	Inarajan
	Inarajan Middle School	Inarajan
	University of Guam Agricultural Experiment Station	Inarajan
	Adacao Elementary School	Mangilao
	George Washington High School	Mangilao
	Price Elementary School	Mangilao
	University of Guam Fieldhouse	Mangilao
	Guam Community College Campus	Mangilao
	University of Guam Marine Lab	Mangilao
	University of Guam Campus	Mangilao
	University of Guam Water and Environmental Research Lab	Mangilao
	Merizo Elementary School	Merizo
	San Miguel Elementary School	Mongmong-Toto-Maite
	Jose L.G. Rios Middle School	Piti
	Harry S. Truman Elementary School	Santa Rita
	Southern High School	Santa Rita
	J.P. Torres Elementary School	Santa Rita

Table E-1 Essential Facilities

Category	Facility Name	Village
Public Schools (cont'd.)	C.L. Taitano Elementary School	Sinajana
	Talofofo Elementary School	Talofofo
	John F. Kennedy High School	Tamuning/Tumon
	Tamuning/Tumon Elementary School	Tamuning/Tumon
	Lyndon B. Johnson Elementary School	Tamuning/Tumon
	Chief James A. Brodie Memorial School	Tamuning/Tumon
	F.Q. Sanchez Elementary School	Umatac
	Simon Sanchez High School	Yigo
	F.B. Leon Guerrero Middle School	Yigo
	Daniel L. Perez Elementary School	Yigo
	Upi Elementary School	Yigo
	Machananao Elementary School	Yigo
	M.U. Lujan Elementary School	Yona
	Guam Mission Academy	Yona
Hotels and Motels	Cliff Hotel	Agana Heights
	Aston Inn On-The-Bay	Agat
	Days Inn	Barrigada
	Harmon Loop Hotel	Dededo
	Starts Guam Resort Hotel	Dededo
	New Marina Hotel	Hagatna
	Ladera Towers	Mangilao
	Plumeria Garden Hotel	Mongmong-Toto-Maite
	Alupang Beach Tower	Tamuning/Tumon
	Days Inn	Tamuning/Tumon

Table E-1 Essential Facilities

Category	Facility Name	Village
Hotels and Motels (cont'd.)	Onward Agana Beach Hotel	Tamuning/Tumon
	Palace Hotel	Tamuning/Tumon
	GITC Hotel	Tamuning/Tumon
	Hilton Hotel	Tamuning/Tumon
	Hotel Maiana	Tamuning/Tumon
	Pacific Islands Club	Tamuning/Tumon
	Fiesta Hotel	Tamuning/Tumon
	Holiday Resort Guam	Tamuning/Tumon
	Hyatt Hotel	Tamuning/Tumon
	Guam Plaza Hotel	Tamuning/Tumon
	Guam Reef Hotel	Tamuning/Tumon
	Tumon Capital Hill Hotel	Tamuning/Tumon
	Westin Hotel	Tamuning/Tumon
	Nikko Hotel	Tamuning/Tumon
	Guam Aurora Resort Villa and Spa	Tamuning/Tumon
	Airport Hotel	Tamuning/Tumon
	Santa Fe On-The-Bay Hotel	Tamuning/Tumon
	Pia Marine Hotel	Tamuning/Tumon
	Pia Resort Hotel	Tamuning/Tumon
	Grand Plaza Hotel	Tamuning/Tumon
	Pacific Bay Hotel	Tamuning/Tumon
	Hunters Inn	Tamuning/Tumon

Table E-1 Essential Facilities

Category	Facility Name	Village
Hotels and Motels (cont'd.)	Royal Orchid Guam Hotel	Tamuning/Tumon
	Outrigger Guam Resort	Tamuning/Tumon
	Ohana Ocean View	Tamuning/Tumon
	The Bayview Hotel	Tamuning/Tumon
	New Century Hotel	Tamuning/Tumon
	Hotel Ypao	Tamuning/Tumon
	Polynesian Hotel/Apartments	Tamuning/Tumon
	Ramada Hotel and Suites	Tamuning/Tumon
	Sheraton Laguna Guam Resort	Tamuning/Tumon
	Tamuning/Tumon Plaza Hotel	Tamuning/Tumon
	Guam Marriott Resort	Tamuning/Tumon
	Golden Motel	Tamuning/Tumon
	Hafa Adai Motel	Tamuning/Tumon
	Leo Palace Resort	Yona

*Sites identified in Table E-1 but not included in the 2014 Guam HMP vulnerability analysis.

Table E-2 Major Utilities

Subcategory	Village
Electric Power Facilities	Dededo
	Dededo
	Piti
	Piti
	Tamuning/Tumon
	Yona
Electric Power Substations	Hagatna
	Barrigada
	Barrigada
	Barrigada
	Dededo
	Mangilao
	Mongmong Toto Mait
	Piti
	Santa Rita
	Santa Rita
	Talofofo
	Tamuning/Tumon
	Tamuning/Tumon
	Tamuning/Tumon
	Tamuning/Tumon

Table E-2 Major Utilities

Subcategory	Village
Electric Power Substations (cont'd.)	Tamuning/Tumon
	Umatac
	Yigo
	Yigo
Electric Power Plants	Dededo
	Dededo
	Piti
	Piti
	Piti
	Piti
	Piti
	Tamuning/Tumon
	Yona
Electric Power Station	Yigo
Potable Water Production Wells	Agana Heights
	Agana Heights
	Barrigada
	Barrigada
	Barrigada
	Barrigada
	Barrigada
	Barrigada

Table E-2 Major Utilities

Subcategory	Village
Potable Water Production Wells (cont'd.)	Barrigada
	Chalan Pago-Ordot
	Chalan Pago-Ordot
	Chalan Pago-Ordot
	Chalan Pago-Ordot
	Chalan Pago-Ordot
	Chalan Pago-Ordot
	Chalan Pago-Ordot
	Chalan Pago-Ordot
	Chalan Pago-Ordot
	Dededo
	Dededo
	Dededo
	Dededo
	Dededo
	Dededo
	Dededo
	Dededo
	Dededo
	Dededo
	Dededo
	Dededo

Table E-2 Major Utilities

Subcategory	Village
Potable Water Production Wells (cont'd.)	Dededo
	Dededo
	Dededo
	Dededo
	Dededo
	Dededo
	Dededo
	Dededo
	Dededo
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	Dededo

Table E-2 Major Utilities

Subcategory	Village
Potable Water Production Wells (cont'd.)	Dededo
	Dededo
	Dededo
	Dededo
	Dededo
	Dededo
	Dededo
	Dededo
	Dededo
	Dededo
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	Dededo
	Dededo

Table E-2 Major Utilities

Subcategory	Village
Potable Water Production Wells (cont'd.)	Dededo
	Dededo
	Dededo
	Dededo
	Dededo
	Dededo
	Hagatna
	Inarajan
	Inarajan
	Mangilao
	Mangilao
	Mangilao
	Mangilao
	Mangilao
	Mangilao
	Mangilao
	Mangilao
	Mangilao
	Mangilao
	Mangilao
	Mangilao
	Mangilao
	Mangilao

Table E-2 Major Utilities

Subcategory	Village
Potable Water Production Wells (cont'd.)	Mongmong-Toto-Maite
	Sinajana
	Sinajana
	Sinajana
	Sinajana
	Sinajana
	Yigo
	Yigo
	Yigo
	Yigo
	Yigo
	Yigo
	Yigo
	Yigo
	Yigo
	Yigo
	Yigo
	Yigo
	Yigo
	Yigo
	Yigo
	Yigo

Table E-2 Major Utilities

Subcategory	Village
Potable Water Enclosed Storage Facilities and Storage Basins	Agana Heights
	Agat
	Agat
	Agat
	Asan
	Asan
	Asan
	Asan
	Barrigada
	Dededo
	Dededo
	Dededo
	Dededo
	Dededo
	Dededo
	Dededo
	Inarajan
	Inarajan
	Inarajan
	Inarajan
	Inarajan
	Mangilao

Table E-2 Major Utilities

Subcategory	Village
Potable Water Enclosed Storage Facilities and Storage Basins (cont'd.)	Mangilao
	Mangilao
	Mangilao
	Mangilao
	Merizo
	Piti
	Santa Rita
	Santa Rita
	Santa Rita
	Santa Rita
	Talofofo
	Talofofo
	Talofofo
	Tamuning/Tumon
	Tamuning/Tumon
	Umatac
	Umatac
	Umatac
	Umatac
	Umatac
	Umatac
	Yigo
	Yigo
	Yigo

Table E-2 Major Utilities

Subcategory	Village
Potable Water Enclosed Storage Facilities and Storage Basins (cont'd.)	Yigo
	Yigo
	Yigo
	Yona
	Yona
	Yona
	Yona
Potable Water Pump Stations	Agana Heights
	Agat
	Agat
	Asan
	Asan
	Asan
	Asan
	Barrigada
	Chalan Pago-Ordot
	Dededo
	Dededo
	Dededo
	Dededo
	Dededo
	Dededo
	Inarajan
	Inarajan

Table E-2 Major Utilities

Subcategory	Village
Potable Water Pump Stations (cont'd.)	Inarajan
	Inarajan
	Inarajan
	Inarajan
	Mangilao
	Mangilao
	Merizo
	Merizo
	Merizo
	Mongmong Toto Maite
	Santa Rita
	Santa Rita
	Santa Rita
	Sinajana
	Talofofo
	Umatac
	Umatac
	Umatac
	Umatac
	Umatac
	Umatac
	Yigo
	Yigo
	Yigo

Table E-2 Major Utilities

Subcategory	Village
Potable Water Pump Stations (cont'd.)	Yigo
	Yigo
	Yigo
	Yona
	Yona
	Yona
	Yona
	Yona
	Yona
Potable Water Treatment Plants (including Chlorination Buildings)	Dededo
	Dededo
	Inarajan
	Santa Rita
	Santa Rita
Wastewater Pump Stations	Agat
	Agat
	Agat
	Asan
	Asan
	Barrigada
	Barrigada
	Barrigada

Table E-2 Major Utilities

Subcategory	Village
Wastewater Pump Stations	Barrigada
	Barrigada
	Chalan Pago-Ordot
	Chalan Pago-Ordot
	Chalan Pago-Ordot
	Chalan Pago-Ordot
	Chalan Pago-Ordot
	Chalan Pago-Ordot
	Chalan Pago-Ordot
	Chalan Pago-Ordot
	Dededo
	Dededo
	Dededo
	Dededo
	Dededo
	Dededo
	Dededo
	Dededo
	Dededo
	Dededo
	Dededo
	Dededo
	Hagatna

Table E-2 Major Utilities

Subcategory	Village
Wastewater Pump Stations	Inarajan
	Inarajan
	Mangilao
	Mangilao
	Mangilao
	Mangilao
	Mangilao
	Mangilao
	Merizo
	Merizo
	Merizo
	Merizo
	Merizo
	Merizo
	Merizo
	Merizo
	Merizo
	Merizo
	Merizo
	Merizo
	Mongmong Toto Mait
	Mongmong Toto Mait
	Mongmong Toto Mait

Table E-2 Major Utilities

Subcategory	Village
Wastewater Pump Stations (cont'd.)	Mongmong Toto Mait
	Piti
	Piti
	Santa Rita
	Sinajana
	Sinajana
	Sinajana
	Talofofo
	Talofofo
	Talofofo
	Talofofo
	Tamuning/Tumon
	Tamuning/Tumon
	Tamuning/Tumon
	Tamuning/Tumon
	Tamuning/Tumon
	Tamuning/Tumon
	Tamuning/Tumon
	Tamuning/Tumon
	Tamuning/Tumon
	Tamuning/Tumon

Table E-2 Major Utilities

Subcategory	Village
Wastewater Pump Stations (cont'd.)	Tamuning/Tumon
	Tamuning/Tumon
	Tamuning/Tumon
	Tamuning/Tumon
	Umatac
	Umatac
	Umatac
	Umatac
	Umatac
	Yigo
	Yigo
	Yona
	Yona
	Yona
Wastewater Treatment Plants	Agat
	Chalan Pago Ordot
	Dededo
	Hagatna
	Inarajan
	Umatac
	Yona

Table E-3 Transportation Systems

Category	Name	Village
Municipal Airport	Guam Airport Authority – Runway (two)	Barrigada
	Guam Airport Authority - Terminal	Barrigada
	Guam Airport Authority – Terminal and Offices	Barrigada
	Guam Airport Authority – Service Hangar	Barrigada
Port Facilities	Fuel Pier F-1	Piti
	Golf Pier	Piti
	Harbor Of Refuge Warehouse	Piti
	Hazmat Station*	Piti
	Hotel Wharf	Piti
	Wharfs F-2 Through F-6	Piti
	Port Container Yard and associated buildings and facilities**	Piti
Traffic Signals	Rt. 2 and Rt. 12	Agat
	Rt. 1 and Rt. 6 (Adelup)	Asan
	Rt. 8 and Tiyan Gate	Barrigada
	Rt. 10 and Mangilao (Pedestrian Crossing)	Barrigada
	Rt. 16 and Revenue and Taxation Building	Barrigada
	Rt. 16 and Rt. 8A (Radio Barrigada)	Barrigada
	Rt. 16 and Guam Main Post Office	Barrigada
	Rt. 16 and Rt. 10A/Rt.25 Overpass	Barrigada
	Rt. 8 and Rt. 10	Barrigada
	Rt. 8 and Rt. 33	Barrigada
	Rt. 10 and Sabanan Ma’agas Rd.	Chalan Pago-Ordot
	Rt. 4 and Rt. 15 (Maimai Rd.)	Chalan Pago-Ordot
	Rt. 4 and Rt. 10	Chalan Pago-Ordot

Table E-3 Transportation Systems

Category	Name	Village
Traffic Signals (cont'd.)	Rt. 4 and Rt. 19, Dero Rd.	Chalan Pago-Ordot
	Rt. 1 and Rt. 27a, Fatima St.	Dededo
	Rt. 16 and Rt. 27 (Harmon Loop)	Dededo
	Rt. 16 and Iglesia Ni Cristo (Pedestrian Crossing)	Dededo
	Rt. 16 and Rt. 27A, Fatima St.	Dededo
	Rt. 1 and Chalan Henry Kaiswer	Dededo
	Rt. 1 and Iglesia Circle (Skate Park)	Dededo
	Rt. 1 and Micronesia Mall (north exit)	Dededo
	Rt. 1 and Rt. 16 (Army Drive)	Dededo
	Rt. 1 and Rt. 26 (Macheche Avenue)	Dededo
	Rt. 1 and Rt. 27 (Harmon Loop/Salisbury)	Dededo
	Rt. 1 and Rt. 28 (Y-Sengsong Road)	Dededo
	Rt. 1 and Rt. 3	Dededo
	Rt. 1 and Wusstig Rd.	Dededo
	Rt. 27 and Compadres Mall	Dededo
	Rt. 27 and JM Guerrero School	Dededo
	Rt. 3 and Rt. 28 (Y-Sengsong Road)	Dededo
	Rt. 1 and Aspinnal Avenue (Boat Basin)	Hagatna
	Rt. 4 and Chalan Santo Papa	Hagatna
	Rt. 4 And Rt. 7A, O'Brien Dr.	Hagatna
	Rt. 1 and 5th Street	Hagatna
	Rt. 1 and Rt. 4 (Paseo Loop)	Hagatna
	Rt. 7A and Chalan Obispo (San Ramon)	Hagatna
	Rt. 10 and Corten Torres St.	Mangilao

Table E-3 Transportation Systems

Category	Name	Village
Traffic Signals (cont'd.)	Rt. 10 and Rt. 32 (University of Guam)	Mangilao
	Rt. 25 and Rt. 26	Mangilao
	Rt. 10 and Rt. 15	Mangilao
	Rt. 8 and Rt. 7A (East O'Brien Dr.)	Mongmong-Toto-Maite
	Rt. 1 and Polaris Point	Piti
	Rt. 1 and Rt. 11 (USO)	Piti
	Rt. 1 and Rt. 6 (Piti Cemetery)	Piti
	Rt. 1 and Rt. 2A	Santa Rita
	Rt. 2A and Rt. 5	Santa Rita
	Rt. 5 and Southern High/Apra Heights	Santa Rita
	Rt. 4 and Chalan Canton Tutujan	Sinajana
	Rt. 1 and Ilipog Dr.	Tamuning/Tumon
	Rt. 1 and Citibank	Tamuning/Tumon
	Rt. 1 and Department of Public Works	Tamuning/Tumon
	Rt. 1 and Rt. 10A, Airport Rd.	Tamuning/Tumon
	Rt. 1 and Rt. 14, Upper San Vit.	Tamuning/Tumon
	Rt. 1 and Rt. 14A (Kmart)	Tamuning/Tumon
	Rt. 1 and Rt. 30 (Gov. Camacho Rd.)	Tamuning/Tumon
	Rt. 1 and Rt. 14B (Ypao Rd.)	Tamuning/Tumon
	Rt. 1 and Rt. 8	Tamuning/Tumon
	Rt. 1 and Saint John	Tamuning/Tumon
	Rt. 1 and Tumon Lane (Pia Marine)	Tamuning/Tumon
	Rt. 1 and Upper San Vitores	Tamuning/Tumon
	Rt. 10 A and Home Depot	Tamuning/Tumon

Table E-3 Transportation Systems

Category	Name	Village
Traffic Signals (cont'd.)	Rt. 14 and Blessed Diego Church	Tamuning/Tumon
	Rt. 14 and Dai-Ichi ped. (Fiesta Resort)	Tamuning/Tumon
	Rt. 14 and Fujita Rd./Happy Landing Rd.	Tamuning/Tumon
	Rt. 14 and Guam Premier Outlets	Tamuning/Tumon
	Rt. 14 and Guam Visitors Bureau	Tamuning/Tumon
	Rt. 14 and Marata Ct. (Sand Castle)	Tamuning/Tumon
	Rt. 14 and PIC (Pedestrian Crossing)	Tamuning/Tumon
	Rt. 14 and Rivera Lane (DFS)	Tamuning/Tumon
	Rt. 14 and Rt. 30 A (Farenholt Ave.)	Tamuning/Tumon
	Rt. 14 and St. Anthony (Pedestrian Crossing)	Tamuning/Tumon
	Rt. 14 and Tumon Sands (Pedestrian Crossing)	Tamuning/Tumon
	Rt. 14 and Westin Hotel	Tamuning/Tumon
	Rt. 14 and Rt. 14A (Marriott Resort)	Tamuning/Tumon
	Rt. 14 and Rt. 14B (Hilton)	Tamuning/Tumon
	Rt. 30 and Rt. 30A	Tamuning/Tumon
	Rt. 1 and Chln. Lujuna (Perez Acres)	Yigo
	Rt. 1 amd Juan Jacinto Rd. (Simon Sanchez)	Yigo
	Rt. 1 amd Rt. 29 (Gayinero Rd.)	Yigo
	Rt. 1 and Rt. 9 (Andersen Air Force Base)	Yigo
	Rt. 4 and Rt. 17	Yona

Table E-3 Transportation Systems

Category	Name	Village
Bridges	Bridge	Asan/Maina
	Bridge	Chalan Pago-Ordot
	Bridge	Hagatna
	Bridge	Hagatna
	Bridge	Hagatna
	Bridge	Inarajan
	Bridge	Inarajan
	Bridge	Inarajan
	Bridge	Inarajan
	Bridge	Merizo
	Bridge	Piti
	Bridge	Tamuning/Tumon
	Bridge	Umatac
	Bridge	Umatac
	Ylig Bridge	Yona
	Pago Bay Bridge	Yona
Bus SubStations	Bus SubStation	Barrigada
	Bus SubStation	Chalan Pago Ordot
	Bus SubStation	Dededo
	Bus SubStation	Inarajan
	Bus SubStation	Agat
	Bus SubStation	Yigo

* Facility identified and analyzed in the 2014 Guam HMP. To be removed from future versions of the plan b/c it to be demolished and removed as part of the PAG modernization effort., ** Sites identified in Table E-1 but not included in the 2014 Guam HMP vulnerability analysis.

Table E-4 Transportation Systems (Major Roads)

Category	Name	Distance (miles)
Major Roads	Pedro Roberto Dr./Route 12	1.50
	Pedro Roberto Dr./Route 5	1.26
	Purple Heart Memorial Hwy.	3.14
	Route 3	5.59
	Route 10a	1.93
	Route 11	2.11
	Route 12	0.47
	Route 15	11.57
	Route 2	9.53
	Route 25	0.60
	Route 2a	0.18
	Route 2a	1.66
	Route 4a	3.24
	Route 6	4.95
	Route 7a	0.01
	Route 7b	0.26
	Route 8	1.74
	Route 9	3.07
	Sgt Roy T Damian Jr. St.	2.96
	Vietnam Veterans Memorial Hwy.	3.57
	Ypao Rd.	0.88
	Army Dr./Route 16	4.32
	Carnation Rd./Route 26	1.41

Appendix F
Vulnerability Analysis Results by Village

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Table F-1 Vulnerability Analysis Results by Village: Total Assets

	Area	Population	Essential Facilities		Major Utilities		Transportation Systems		GBS	
Village	**Square Miles**	**No.**	**No.**	**Value ($)**	**No.**	**Value ($)**	**No.**	**Value ($)**	**No.**	**Value ($)**
Agana Heights (Passan)	1.03	3,808	6	5,401,284	4	5,878,978	1	17,229	906	83,197,861
Agat	10.62	4,917	20	43,596,355	9	24,031,168	2	331,760	1372	117,024,341
Asan	5.67	2,137	5	9,621,711	10	23,236,184	3	1,019,093	720	70,635,437
Barrigada	8.50	8,875	24	28,497,484	17	11,722,547	15	7,602,065	2833	344,645,729
Chalan Pago-Ordot	5.65	6,822	8	6,516,256	19	12,738,197	7	1,745,815	1782	160,219,478
Dededo	30.25	44,943	35	40,617,894	96	125,123,786	18	4,137,438	9889	1,577,218,233
Hagatna (Agana)	0.85	1,051	40	28,789,709	4	6,796,932	10	3,763,639	628	218,363,375
Inarajan	18.74	2,273	15	19,998,666	17	41,029,583	6	2,878,632	1028	70,729,139
Mangilao	10.28	15,191	28	61,267,439	28	37,309,527	5	1,192,445	3169	469,487,557
Merizo	6.12	1,850	10	4,148,678	16	13,337,842	2	775,820	674	55,473,231
Mongmong-Toto-Maite	1.82	6,825	8	8,212,577	7	4,492,942	2	300,159	1319	204,600,900
Piti	7.35	1,454	19	12,150,068	13	275,906,861	11	75,342,599	811	115,581,405
Santa Rita	16.42	6,084	7	26,332,798	12	28,483,393	5	972,823	2662	209,615,321
Sinajana	0.89	2,592	7	3,273,776	9	3,006,870	2	261,408	699	70,123,657
Talofofo	17.80	3,050	8	2,753,783	9	19,811,254	1	74,411	971	88,713,439
Tamuning/Tumon	5.70	19,685	83	520,299,536	23	72,745,137	30	7,875,362	3547	1,463,769,916
Umatac	6.09	782	9	3,116,080	19	46,126,248	3	1,451,186	264	17,304,647
Yigo	35.78	20,539	11	12,811,622	33	55,674,951	6	1,189,513	4906	450,131,582
Yona	20.25	6,480	12	68,620,072	17	77,406,715	4	1,776,834	1889	333,241,884
Total	209.82	159,358	355	906,025,789	362	884,859,115	133	112,708,230	40069	6,120,077,132

Table F-2 Vulnerability Analysis Results by Village: Proportion of Total Assets

	Area	Population	Essential Facilities		Major Utilities		Transportation Systems		GBS	
Village	% of Sq. Miles	% of No.	% of No.	% of Value	% of No.	% of Value	% of No.	% of Value	% of No.	% of Value
Agana Heights (Passan)	0.49	2.39	1.69	0.60	1.10	0.66	0.75	0.02	2.26	1.36
Agat	5.06	3.09	5.63	4.81	2.49	2.72	1.50	0.29	3.42	1.91
Asan	2.70	1.34	1.41	1.06	2.76	2.63	2.26	0.90	1.80	1.15
Barrigada	4.05	5.57	6.76	3.15	4.70	1.32	11.28	6.74	7.07	5.63
Chalan Pago-Ordot	2.69	4.28	2.25	0.72	5.25	1.44	5.26	1.55	4.45	2.62
Dededo	14.42	28.20	9.86	4.48	26.52	14.14	13.53	3.67	24.68	25.77
Hagatna (Agana)	0.41	0.66	11.27	3.18	1.10	0.77	7.52	3.34	1.57	3.57
Inarajan	8.93	1.43	4.23	2.21	4.70	4.64	4.51	2.55	2.57	1.16
Mangilao	4.90	9.53	7.89	6.76	7.73	4.22	3.76	1.06	7.91	7.67
Merizo	2.92	1.16	2.82	0.46	4.42	1.51	1.50	0.69	1.68	0.91
Mongmong-Toto-Maite	0.87	4.28	2.25	0.91	1.93	0.51	1.50	0.27	3.29	3.34
Piti	3.50	0.91	5.35	1.34	3.59	31.18	8.27	66.85	2.02	1.89
Santa Rita	7.83	3.82	1.97	2.91	3.31	3.22	3.76	0.86	6.64	3.43
Sinajana	0.42	1.63	1.97	0.36	2.49	0.34	1.50	0.23	1.74	1.15
Talofofo	8.48	1.91	2.25	0.30	2.49	2.24	0.75	0.07	2.42	1.45
Tamuning/ Tumon	2.72	12.35	23.38	57.43	6.35	8.22	22.56	6.99	8.85	23.92
Umatac	2.90	0.49	2.54	0.34	5.25	5.21	2.26	1.29	0.66	0.28
Yigo	17.05	12.89	3.10	1.41	9.12	6.29	4.51	1.06	12.24	7.35
Yona	9.65	4.07	3.38	7.57	4.70	8.75	3.01	1.58	4.71	5.45

Table F-3 Vulnerability Analysis Results by Village: Total Affected by Fault Proximity

Village	Area	Population	Essential Facilities		Major Utilities		Transportation Systems		GBS	
	Square Miles	No.	No.	Value ($)	No.	Value ($)	No.	Value ($)	No.	Value ($)
Agana Heights (Passan)	0.37	1,373	1	1,180,000	1	190,359	1	12,530	149	13,682,670
Agat	2.19	1,014	1	33,345,000	0	0	2	266,047	140	11,941,300
Asan	2.66	1,003	1	8,260,000	4	6,741,404	2	294,960	323	31,687,915
Barrigada	2.12	2,213	4	10,820,000	5	1,383,008	7	5,949,496	620	75,425,480
Chalan Pago-Ordot	0.74	894	1	1,180,000	0	0	0	0	47	4,225,770
Dededo	2.56	3,805	1	750,000	10	13,001,100	3	580,624	591	94,259,772
Hagatna (Agana)	0.43	535	25	17,847,998	2	744,542	7	2,457,094	461	160,295,232
Inarajan	6.11	7,42	3	711,714	4	11,550,650	2	725,776	102	7,017,906
Mangilao	0.81	1,198	0	0	3	6,119,832	1	7,288	442	65,482,300
Merizo	1.74	526	2	688,844	8	4,541,363	1	24,961	217	17,859,968
Mongmong-Toto-Maite	0.51	1,912	3	2,830,000	2	811,931	2	269,460	261	40,485,798
Piti	1.17	232	0	0	0	0	1	966	32	4,560,544
Santa Rita	4.19	1,553	2	1,394,743	6	17,003,114	1	50,703	786	61,892,784
Sinajana	0	0	0	0	0	0	0	0	0	0
Talofofo	5.15	883	23	82,619,589	4	12,017,065	1	13,461	53	4,842,239
Tamuning/ Tumon	1.74	6,008	0	0	10	34,523,314	7	1,991,188	942	388,742,676
Umatac	2.28	293	0	0	4	16,114,062	1	28,671	25	1,638,700
Yigo	7.48	4,295	4	7,275,745	16	28,633,454	3	340,995	1065	97,714,815
Yona	3.61	1,155	0	0	4	23,790,352	1	14,704	129	22,757,148
Total	45.86	29,634	71	168,903,633	83	177,165,550	43	13,028,925	6,385	1,104,513,017

Table F-4 Vulnerability Analysis Results by Village: Proportion Affected by Fault Proximity

Village	Area	Population	Essential Facilities		Major Utilities		Transportation Systems		GBS	
	% of Sq. Miles	% of No.	% of No.	% of Value	% of No.	% of Value	% of No.	% of Value	% of No.	% of Value
Agana Heights (Passan)	35.92	36.06	16.67	21.85	25.00	3.24	100.00	72.73	16.45	16.45
Agat	20.62	20.62	5.00	76.49	0.00	0.00	100.00	80.19	10.20	10.20
Asan	46.91	46.93	20.00	85.85	40.00	29.01	66.67	28.94	44.86	44.86
Barrigada	24.94	24.94	16.67	37.97	29.41	11.80	46.67	78.26	21.88	21.88
Chalan Pago-Ordot	13.10	13.10	12.50	18.11	0.00	0.00	0.00	0.00	2.64	2.64
Dededo	8.46	8.47	2.86	1.85	10.42	10.39	16.67	14.03	5.98	5.98
Hagatna (Agana)	50.59	50.90	62.50	61.99	50.00	10.95	70.00	65.29	73.41	73.41
Inarajan	32.60	32.64	20.00	3.56	23.53	28.15	33.33	25.21	9.92	9.92
Mangilao	7.88	7.89	0.00	0.00	10.71	16.40	20.00	0.61	13.95	13.95
Merizo	28.43	28.43	20.00	16.60	50.00	34.05	50.00	3.22	32.20	32.20
Mongmong-Toto-Maite	28.02	28.01	37.50	34.46	28.57	18.07	100.00	89.77	19.79	19.79
Piti	15.92	15.96	0.00	0.00	0.00	0.00	9.09	0.00	3.95	3.95
Santa Rita	25.52	25.53	28.57	5.30	50.00	59.69	20.00	5.21	29.53	29.53
Sinajana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Talofofo	28.93	28.95	287.50	3000.22	44.44	60.66	100.00	18.09	5.46	5.46
Tamuning/ Tumon	30.53	30.52	0.00	0.00	43.48	47.46	23.33	25.28	26.56	26.56
Umatac	37.44	37.47	0.00	0.00	21.05	34.93	33.33	1.98	9.47	9.47
Yigo	20.91	20.91	36.36	56.79	48.48	51.43	50.00	28.67	21.71	21.71
Yona	17.83	17.82	0.00	0.00	23.53	30.73	25.00	0.83	6.83	6.83
Total	21.86	18.60	20.00	18.64	22.93	20.02	32.33	11.56	15.94	18.05

Table F-5 Vulnerability Analysis Results by Village: Total Affected by Very High Liquefaction

	Area	Population	Essential Facilities		Major Utilities		Transportation Systems		GBS	
Village	Square Miles	No.	No.	Value ($)	No.	Value ($)	No.	Value ($)	No.	Value ($)
Agana Heights (Passan)	0	0	0	0	0	0	0	0	0	0
Agat	0	0	0	0	0	0	0	0	0	0
Asan	0	0	0	0	0	0	0	0	0	0
Barrigada	0	0	0	0	0	0	0	0	0	0
Chalan Pago-Ordot	0	0	0	0	0	0	0	0	0	0
Dededo	0	0	0	0	0	0	0	0	0	0
Hagatna (Agana)	0.12	150	14	12,498,834	0	0	4	907,323	103	35,814,336
Inarajan	0	0	0	0	0	0	0	0	0	0
Mangilao	0	0	0	0	0	0	0	0	0	0
Merizo	0	0	0	0	0	0	0	0	0	0
Mongmong-Toto-Maite	0	0	0	0	0	0	0	0	0	0
Piti	0.17	34	1	1,180,000	2	132,319,860	1	55,125,000	62	8,836,054
Santa Rita	0.22	82	0	0	0	0	1	55	40	3,149,760
Sinajana	0	0	0	0	0	0	0	0	0	0
Talofofo	0	0	0	0	0	0	0	0	0	0
Tamuning/ Tumon	0	0	0	0	0	0	0	0	0	0
Umatac	0	0	0	0	0	0	0	0	0	0
Yigo	0	0	0	0	0	0	0	0	0	0
Yona	0	0	0	0	0	0	0	0	0	0
Total	0.51	266	15	13,678,834	2	132,319,860	6	56,032,379	205	47,800,150

Table F-6 Vulnerability Analysis Results by Village: Proportion Affected by Very High Liquefaction

Village	Area	Population	Essential Facilities		Major Utilities		Transportation Systems		GBS	
	% of Sq. Miles	% of No.	% of No.	% of Value	% of No.	% of Value	% of No.	% of Value	% of No.	% of Value
Agana Heights (Passan)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Asan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Barrigada	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chalan Pago-Ordot	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dededo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hagatna (Agana)	14.12	14.27	35.00	43.41	0.00	0.00	40.00	24.11	16.40	16.40
Inarajan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mangilao	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Merizo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mongmong-Toto-Maite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Piti	2.31	2.34	5.26	9.71	15.38	47.96	9.09	73.17	7.64	7.64
Santa Rita	1.34	1.35	0.00	0.00	0.00	0.00	20.00	0.01	1.50	1.50
Sinajana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Talofofo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tamuning/ Tumon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Umatac	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Yigo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Yona	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	0.24	0.17	4.23	1.51	0.55	14.95	4.51	49.71	0.51	0.78

Table F-7 Vulnerability Analysis Results by Village: Total Affected by High Liquefaction

Village	Area	Population	Essential Facilities		Major Utilities		Transportation Systems		GBS	
	Square Miles	No.	No.	Value ($)	No.	Value ($)	No.	Value ($)	No.	Value ($)
Agana Heights (Passan)	0.00	0	0	0	0	0	0	0	0	0
Agat	0.00	0	0	0	0	0	0	0	0	0
Asan	0.00	0	0	0	0	0	0	0	0	0
Barrigada	00.0	0	0	0	0	0	0	0	0	0
Chalan Pago-Ordot	0.00	0	0	0	0	0	0	0	0	0
Dededo	0.11	164	0	0	0	0	0	0	0	0
Hagatna (Agana)	0.01	13	0	0	1	621,572	2	252,512	25	8,692,800
Inarajan	0.00	0	0	0	0	0	0	0	0	0
Mangilao	0.00	0	0	0	0	0	0	0	0	0
Merizo	0.12	37	1	237,238	0	0	0	0	0	0
Mongmong-Toto-Maite	0.00	0	0	0	0	0	0	0	0	0
Piti	0.74	147	1	1,180,000	5	69,139,550	4	10,056,237	125	17,814,625
Santa Rita	1.12	415	0	0	2	674,118	2	20,935	173	13,622,712
Sinajana	0.00	0	0	0	0	0	0	0	0	0
Talofofo	0.00	0	0	0	0	0	0	0	0	0
Tamuning/ Tumon	0.16	553	9	60,064,238	3	1,864,716	5	1,250,000	54	22,284,612
Umatac	0.00	0	0	0	0	0	0	0	0	0
Yigo	0.23	133	0	0	0	0	0	0	2	183,502
Yona	0.00	0	0	0	0	0	0	0	0	0
Total	2.49	1,462	11	61,481,476	11	72,299,956	13	11,579,684	379	62,598,251

Table F-8 Vulnerability Analysis Results by Village: Proportion Affected by High Liquefaction

	Area	Population	Essential Facilities		Major Utilities		Transportation Systems		GBS	
Village	% of Sq. Miles	% of No.	% of No.	% of Value	% of No.	% of Value	% of No.	% of Value	% of No.	% of Value
Agana Heights (Passan)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Asan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Barrigada	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chalan Pago-Ordot	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dededo	0.36	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hagatna (Agana)	1.18	1.24	0.00	0.00	25.00	9.14	20.00	6.71	3.98	3.98
Inarajan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mangilao	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Merizo	1.96	2.00	10.00	5.72	0.00	0.00	0.00	0.00	0.00	0.00
Mongmong-Toto-Maite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Piti	10.07	10.11	5.26	9.71	38.46	25.06	36.36	13.35	15.41	15.41
Santa Rita	6.82	6.82	0.00	0.00	16.67	2.37	40.00	2.15	6.50	6.50
Sinajana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Talofofo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tamuning/ Tumon	2.81	2.81	10.84	11.54	13.04	2.56	16.67	15.87	1.52	1.52
Umatac	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Yigo	0.64	0.65	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04
Yona	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	1.19	0.92	3.10	6.79	3.04	8.17	9.77	10.27	0.95	1.02

Table F-9 Vulnerability Analysis Results by Village: Total Affected by Flooding

Village	Area	Population	Essential Facilities		Major Utilities		Transportation Systems		GBS	
	Square Miles	No.	No.	Value ($)	No.	Value ($)	No.	Value ($)	No.	Value ($)
Agana Heights (Passan)	0.02	75	0	0	0	0	1	1,365	0	0
Agat	0.83	385	9	36,625,640	2	1,243,144	2	288,554	364	31,047,380
Asan	0.12	46	0	0	0	0	2	691,223	22	2,158,310
Barrigada	0.01	11	0	0	0	0	0	0	2	243,308
Chalan Pago-Ordot	0.40	484	1	237,238	4	2,055,075	2	254,256	36	3,236,760
Dededo	0.07	105	0	0	0	0	0	0	0	0
Hagatna (Agana)	0.54	672	25	16,767,415	2	6,483,603	8	2,751,184	402	139,780,224
Inarajan	1.10	134	7	1,535,607	3	1,433,503	5	2,802,413	161	11,077,283
Mangilao	0.15	222	0	0	0	0	0	0	8	1,185,200
Merizo	0.84	254	2	277,238	10	6,215,720	2	748,490	372	30,617,088
Mongmong-Toto-Maite	0.34	1275	0	0	0	0	0	0	48	7,445,664
Piti	1.08	214	11	7,323,428	2	25,384,984	8	66,323,573	227	32,351,359
Santa Rita	1.58	586	0	0	0	0	1	6,757	194	15,276,336
Sinajana	0.18	523	0	0	0	0	0	0	7	702,240
Talofofo	1.19	204	1	237,238	0	0	1	5,298	21	1,918,623
Tamuning/Tumon	0.55	1,900	15	70,392,649	3	2,454,050	3	965,274	286	118,025,908
Umatac	0.29	38	3	809,173	1	621,572	2	692,052	25	1,638,700
Yigo	0.28	161	0	0	0	0	0	0	0	0
Yona	0.83	266	2	474,476	0	0	3	1,385,882	7	1,234,884
Total	10.4	7,555	76	134,680,102	27	45,891,651	40	76,916,320	2,182	397,939,267

Table F-10 Vulnerability Analysis Results by Village: Proportion Affected by Flooding

Village	Area	Population	Essential Facilities		Major Utilities		Transportation Systems		GBS	
	% of Sq. Miles	% of No.	% of No.	% of Value	% of No.	% of Value	% of No.	% of Value	% of No.	% of Value
Agana Heights (Passan)	1.94	1.97	0.00	0.00	0.00	0.00	100.00	7.92	0.00	0.00
Agat	7.82	7.83	45.00	84.01	22.22	5.17	100.00	86.98	26.53	26.53
Asan	2.12	2.15	0.00	0.00	0.00	0.00	66.67	67.83	3.06	3.06
Barrigada	0.12	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.07
Chalan Pago-Ordot	7.08	7.09	12.50	3.64	21.05	16.13	28.57	14.56	2.02	2.02
Dededo	0.23	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hagatna (Agana)	63.53	63.94	62.50	58.24	50.00	95.39	80.00	73.10	64.01	64.01
Inarajan	5.87	5.90	46.67	7.68	17.65	3.49	83.33	97.35	15.66	15.66
Mangilao	1.46	1.46	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.25
Merizo	13.73	13.73	20.00	6.68	62.50	46.60	100.00	96.48	55.19	55.19
Mongmong-Toto-Maite	18.68	18.68	0.00	0.00	0.00	0.00	0.00	0.00	3.64	3.64
Piti	14.69	14.72	57.89	60.27	15.38	9.20	72.73	88.03	27.99	27.99
Santa Rita	9.62	9.63	0.00	0.00	0.00	0.00	20.00	0.69	7.29	7.29
Sinajana	20.22	20.18	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00
Talofofo	6.69	6.69	12.50	8.61	0.00	0.00	100.00	7.12	2.16	2.16
Tamuning/ Tumon	9.65	9.65	18.07	13.53	13.04	3.37	10.00	12.26	8.06	8.06
Umatac	4.76	4.86	33.33	25.97	5.26	1.35	66.67	47.69	9.47	9.47
Yigo	0.78	0.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Yona	4.10	4.10	16.67	0.69	0.00	0.00	75.00	78.00	0.37	0.37
Total	4.96	4.74	21.41	14.86	7.46	5.19	30.08	68.24	5.45	6.50

Table F-11 Vulnerability Analysis Results by Village: Total Affected by Air Permitted Facilities

Village	Area	Population	Essential Facilities		Major Utilities		Transportation Systems		GBS	
	Square Miles	No.	No.	Value ($)	No.	Value ($)	No.	Value ($)	No.	Value ($)
Agana Heights (Passan)	0.67	2,485	6	5,401,284	3	5,688,619	1	9,839	797	73,278,637
Agat	0	0	0	0	0	0	0	0	0	0
Asan	0.03	12	0	0	0	0	0	0	2	196,210
Barrigada	0.76	794	2	3,014,000	0	0	2	314,200	331	40,267,474
Chalan Pago-Ordot	0	0	0	0	0	0	0	0	0	0
Dededo	7.29	10,833	25	28,004,521	37	72,251,718	17	3,797,676	4642	740,361,864
Hagatna (Agana)	0.69	859	38	27,372,471	3	6,673,962	9	3,064,914	442	153,688,704
Inarajan	0	0	0	0	0	0	0	0	0	0
Mangilao	0.03	45	0	0	0	0	0	0	19	2,814,850
Merizo	0	0	0	0	0	0	0	0	0	0
Mongmong-Toto-Maite	1.05	3,935	4	4,784,000	4	3,059,439	2	281,478	746	115,718,028
Piti	3.39	671	15	9,315,592	12	275,285,289	6	1,543,271	485	69,120,745
Santa Rita	1.52	564	0	0	0	0	3	538,405	252	19,843,488
Sinajana	0.41	1,190	7	3,273,776	5	1,383,008	2	256,148	466	46,749,120
Talofofo	3.12	535	5	2,042,069	8	19,189,682	1	31,968	681	62,218,203
Tamuning/ Tumon	2.45	8,460	34	137,056,130	6	49,150,250	11	3,052,637	1761	726,725,958
Umatac	0	0	0	0	0	0	0	0	0	0
Yigo	4.80	2,756	6	6,932,426	14	25,773,353	4	570,727	1461	134,048,211
Yona	3.15	1,008	0	0	7	45,940,111	0	0	259	45,690,708
Total	29.37	34,147	142	227,196,269	99	504,395,431	58	13,461,264	12,344	2,230,722,200

Table F-12 Vulnerability Analysis Results by Village: Proportion Affected by Air Permitted Facilities

	Area	Population	Essential Facilities		Major Utilities		Transportation Systems		GBS	
Village	**% of Sq. Miles**	**% of No.**	**% of No.**	**% of Value**	**% of No.**	**% of Value**	**% of No.**	**% of Value**	**% of No.**	**% of Value**
Agana Heights (Passan)	65.05	65.26	100.00	100.00	75.00	96.76	100.00	57.11	87.97	88.08
Agat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Asan	0.53	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.28
Barrigada	8.94	8.95	8.33	10.58	0.00	0.00	13.33	4.13	11.68	11.68
Chalan Pago-Ordot	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dededo	24.10	24.10	71.43	68.95	38.54	57.74	94.44	91.79	46.94	46.94
Hagatna (Agana)	81.18	81.73	95.00	95.08	75.00	98.19	90.00	81.43	70.38	70.38
Inarajan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mangilao	0.29	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.60
Merizo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mongmong-Toto-Maite	57.69	57.66	50.00	58.25	57.14	68.09	100.00	93.78	56.56	56.56
Piti	46.12	46.15	78.95	76.67	92.31	99.77	54.55	2.05	59.80	59.80
Santa Rita	9.26	9.27	0.00	0.00	0.00	0.00	60.00	55.34	9.47	9.47
Sinajana	46.07	45.91	100.00	100.00	55.56	45.99	100.00	97.99	66.67	66.67
Talofofo	17.53	17.54	62.50	74.16	88.89	96.86	100.00	42.96	70.13	70.13
Tamuning/ Tumon	42.98	42.98	40.96	26.34	26.09	67.56	36.67	38.76	49.65	49.65
Umatac	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Yigo	13.42	13.42	54.55	54.11	42.42	46.29	66.67	47.98	29.78	29.78
Yona	15.56	15.56	0.00	0.00	41.18	59.35	0.00	0.00	13.71	13.71
Total	14.00	21.43	40.00	25.08	27.35	57.00	43.61	11.94	30.81	36.45

Table F-13 Vulnerability Analysis Results by Village: Total Affected by Water Permitted Facilities

Village	Area	Population	Essential Facilities		Major Utilities		Transportation Systems		GBS	
	Square Miles	No.	No.	Value ($)	No.	Value ($)	No.	Value ($)	No.	Value ($)
Agana Heights (Passan)	0.45	1,669	2	3,023,000	3	5,688,619	1	15,109	246	22,590,180
Agat	0	0	0	0	0	0	0	0	606	51,688,770
Asan	0.04	16	0	0	0	0	0	0	136	13,342,280
Barrigada	1.72	1,796	5	4,933,007	4	1,192,649	5	5,347,047	834	101,459,436
Chalan Pago-Ordot	1.21	1,462	1	237,238	4	7,295,534	3	526,070	415	37,312,650
Dededo	2.02	3,002	0	0	4	6,864,321	1	3,866	3816	608,621,472
Hagatna (Agana)	0.63	784	38	27,372,471	3	6,606,573	9	3,067,584	31	10,779,072
Inarajan	1.78	216	1	237,238	4	11,550,650	2	711,124	425	29,241,275
Mangilao	0.99	1,464	12	32,887,192	1	190,359	2	268,576	1043	154,520,450
Merizo	0.67	203	0	0	2	1,243,144	1	14,392	288	23,703,552
Mongmong-Toto-Maite	0.04	150	1	1,400,000	0	0	2	254,864	400	62,047,200
Piti	3.17	628	16	11,438,354	13	275,906,861	10	75,053,531	149	21,235,033
Santa Rita	6.97	2,583	3	23,417,849	7	17,055,660	3	611,710	1009	79,452,696
Sinajana	0	0	0	0	0	0	0	0	88	8,828,160
Talofofo	2.00	343	1	237,238	4	11,427,733	1	22,919	426	38,920,638
Tamuning/ Tumon	2.10	7,251	18	17,950,913	8	36,167,854	13	3,493,448	706	291,350,668
Umatac	1.08	139	7	2,766,663	11	19,015,666	3	1,401,061	175	11,470,900
Yigo	0	0	0	0	0	0	0	0	2,150	197,264,650
Yona	5.76	1,843	2	64,804,564	7	16,249,516	2	740,243	718	126,663,816
Total	30.63	23,549	107	190,705,727	75	416,455,139	58	91,531,545	13,661	1,890,492,898

Table F-14 Vulnerability Analysis Results by Village: Proportion Affected by Water Permitted Facilities

Village	Area	Population	Essential Facilities		Major Utilities		Transportation Systems		GBS	
	% of Sq. Miles	% of No.	% of No.	% of Value	% of No.	% of Value	% of No.	% of Value	% of No.	% of Value
Agana Heights (Passan)	43.69	43.83	33.33	55.97	75.00	96.76	100.00	87.70	27.15	27.15
Agat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	44.17	44.17
Asan	0.71	0.75	0.00	0.00	0.00	0.00	0.00	0.00	18.89	18.89
Barrigada	20.24	20.24	20.83	17.31	23.53	10.17	33.33	70.34	29.44	29.44
Chalan Pago-Ordot	21.42	21.43	12.50	3.64	21.05	57.27	42.86	30.13	23.29	23.29
Dededo	6.68	6.68	0.00	0.00	4.17	5.49	5.56	0.09	38.59	38.59
Hagatna (Agana)	74.12	74.60	95.00	95.08	75.00	97.20	90.00	81.51	4.94	4.94
Inarajan	9.50	9.50	6.67	1.19	23.53	28.15	33.33	24.70	41.34	41.34
Mangilao	9.63	9.64	42.86	53.68	3.57	0.51	40.00	22.52	32.91	32.91
Merizo	10.95	10.97	0.00	0.00	12.50	9.32	50.00	1.86	42.73	42.73
Mongmong-Toto-Maite	2.20	2.20	12.50	17.05	0.00	0.00	100.00	84.91	30.33	30.33
Piti	43.13	43.19	84.21	94.14	100.00	100.00	90.91	99.62	18.37	18.37
Santa Rita	42.45	42.46	42.86	88.93	58.33	59.88	60.00	62.88	37.90	37.90
Sinajana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.59	12.59
Talofofo	11.24	11.25	12.50	8.61	44.44	57.68	100.00	30.80	43.87	43.87
Tamuning/ Tumon	36.84	36.84	21.69	3.45	34.78	49.72	43.33	44.36	19.90	19.90
Umatac	17.73	17.77	77.78	88.79	57.89	41.23	100.00	96.55	66.29	66.29
Yigo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	43.82	43.82
Yona	28.44	28.44	16.67	94.44	41.18	20.99	50.00	41.66	38.01	38.01
Total	14.60	14.78	30.14	21.05	20.72	47.06	43.61	81.21	34.09	30.89

Table F-15 Vulnerability Analysis Results by Village: Total Affected by Hardfill Permitted Facilities

	Area	Population	Essential Facilities		Major Utilities		Transportation Systems		GBS	
Village	**Square Miles**	**No.**	**No.**	**Value ($)**	**No.**	**Value ($)**	**No.**	**Value ($)**	**No.**	**Value ($)**
Agana Heights	0.71	2,633	6	5,401,284	3	5,688,619	1	17,229	694	63,730,020
Agat	0	0	0	0	0	0	0	0	0	0
Asan	0.31	117	1	140,932	2	5,498,260	1	5,878	148	14,519,540
Barrigada	1.61	1,681	0	0	2	811,931	1	1,596	615	74,817,210
Chalan Pago-Ordot	3.52	4,251	6	5,099,018	14	5,252,304	6	1,038,848	1319	118,591,290
Dededo	0	0	0	0	0	0	0	0	0	0
Hagatna	0.75	933	38	27,372,471	4	6,796,932	9	3,073,201	597	207,584,064
Inarajan	0	0	0	0	0	0	0	0	0	0
Mangilao	3.69	5,454	12	9,249,458	8	2,385,298	4	858,693	1122	166,224,300
Merizo	0	0	0	0	0	0	0	0	0	0
Mongmong-Toto-Maite	0.14	525	1	1,400,000	0	0	2	258,432	134	20,785,812
Piti	0	0	0	0	0	0	0	0	0	0
Santa Rita	0	0	0	0	0	0	0	0	0	0
Sinajana	0.07	204	1	112,179	2	811,931	0	0	99	9,931,680
Talofofo	0	0	0	0	0	0	0	0	0	0
Tamuning/T	0.07	242	3	809,173	0	0	3	948,953	47	19,395,866
Umatac	0	0	0	0	0	0	0	0	0	0
Yigo	11.06	6,350	6	7,091,303	13	30,455,766	4	604,906	3649	334,799,399
Yona	0.4	128	0	0	0	0	0	0	0	0
Total	22.33	22,518	74	56,675,818	48	57,701,041	31	6,807,736	8,424	1,030,379,181

Table F-16 Vulnerability Analysis Results by Village: Proportion Affected by Hardfill Permitted Facilities

Village	Area	Population	Essential Facilities		Major Utilities		Transportation Systems		GBS	
	% of Sq. Miles	% of No.	% of No.	% of Value	% of No.	% of Value	% of No.	% of Value	% of No.	% of Value
Agana Heights (Passan)	68.93	69.14	100.00	100.00	75.00	96.76	100.00	100.00	76.60	76.60
Agat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Asan	5.47	5.47	20.00	1.46	20.00	23.66	33.33	0.58	20.56	20.56
Barrigada	18.94	18.94	0.00	0.00	11.76	6.93	6.67	0.02	21.71	21.71
Chalan Pago-Ordot	62.30	62.31	75.00	78.25	73.68	41.23	85.71	59.51	74.02	74.02
Dededo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hagatna (Agana)	88.24	88.77	95.00	95.08	100.00	100.00	90.00	81.66	95.06	95.06
Inarajan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mangilao	35.89	35.90	42.86	15.10	28.57	6.39	80.00	72.01	35.41	35.41
Merizo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mongmong-Toto-Maite	7.69	7.69	12.50	17.05	0.00	0.00	100.00	86.10	10.16	10.16
Piti	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Santa Rita	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sinajana	7.87	7.87	14.29	3.43	22.22	27.00	0.00	0.00	14.16	14.16
Talofofo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tamuning/Tumon	1.23	1.23	3.61	0.16	0.00	0.00	10.00	12.05	1.33	1.33
Umatac	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Yigo	30.91	30.92	54.55	55.35	39.39	54.70	66.67	50.85	74.38	74.38
Yona	1.98	1.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	10.64	14.13	20.85	6.26	13.26	6.52	23.31	6.04	21.02	16.84

Table F-17 Vulnerability Analysis Results by Village: Total Affected by Pre-CERCLIS Facilities

Village	Area	Population	Essential Facilities		Major Utilities		Transportation Systems		GBS	
	Square Miles	No.	No.	Value ($)	No.	Value ($)	No.	Value ($)	No.	Value ($)
Agana Heights (Passan)	1.03	3,808	6	5,401,284	4	5,878,978	1	17,229	906	83,288,107
Agat	5.51	2,551	14	40,196,698	5	17,720,977	2	301,023	1189	101,415,755
Asan	5.48	2,065	5	9,621,711	10	23,236,184	3	1,016,273	713	69,948,865
Barrigada	7.98	8,329	22	19,057,484	16	6,414,646	15	7,600,494	2609	317,395,286
Chalan Pago-Ordot	5.51	6,654	8	6,516,256	19	12,738,197	7	1,745,426	1755	157,792,050
Dededo	18.27	27,149	23	25,760,873	33	25,372,311	16	3,578,919	4575	729,675,900
Hagatna (Agana)	0.85	1,051	40	28,789,709	4	6,796,932	10	3,763,639	628	218,363,136
Inarajan	4.18	507	2	571,935	2	380,718	3	1,416,910	357	24,562,671
Mangilao	5.23	7,730	26	60,792,963	23	36,357,732	5	1,138,555	2633	390,078,950
Merizo	2.19	662	1	237,238	4	2,486,288	1	31,561	267	21,975,168
Mongmong-Toto-Maite	1.82	6,820	8	8,212,577	7	4,492,942	2	300,159	1319	204,600,642
Piti	6.98	1,381	19	12,150,068	13	275,906,861	11	75,342,599	772	110,023,124
Santa Rita	7.02	2,601	7	26,332,798	8	22,932,587	4	653,479	1258	99,059,952
Sinajana	0.89	2,584	7	3,273,776	9	3,006,870	2	261,408	699	70,123,680
Talofofo	8.77	1,503	7	2,516,545	9	19,811,254	1	69,312	962	87,891,206
Tamuning/ Tumon	5.70	19,682	83	520,299,536	23	72,745,137	30	7,875,362	3547	146,376,886
Umatac	4.41	567	5	2,203,916	13	38,449,996	2	742,811	176	11,536,448
Yigo	29.90	17,165	8	12,224,967	32	55,053,379	5	917,171	4073	373,701,823
Yona	17.90	5,727	10	68,145,596	17	77,406,715	4	1,754,081	1768	311,896,416
Total	139.62	118,555	301	852,305,930	251	707,188,704	124	108,526,413	30,206	3,529,706,065

Table F-18 Vulnerability Analysis Results by Village: Proportion Affected by Pre-CERCLIS Facilities

	Area	Population	Essential Facilities		Major Utilities		Transportation Systems		GBS	
Village	**% of Sq. Miles**	**% of No.**	**% of No.**	**% of Value**	**% of No.**	**% of Value**	**% of No.**	**% of Value**	**% of No.**	**% of Value**
Agana Heights (Passan)	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.11
Agat	51.88	51.88	70.00	92.20	55.56	73.74	100.00	90.74	86.66	86.66
Asan	96.65	96.63	100.00	100.00	100.00	100.00	100.00	99.72	99.03	99.03
Barrigada	93.88	93.85	91.67	66.87	94.12	54.72	100.00	99.98	92.09	92.09
Chalan Pago-Ordot	97.52	97.54	100.00	100.00	100.00	100.00	100.00	99.98	98.48	98.48
Dededo	60.40	60.41	65.71	63.42	34.38	20.28	88.89	86.50	46.26	46.26
Hagatna (Agana)	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Inarajan	22.31	22.31	13.33	2.86	11.76	0.93	50.00	49.22	34.73	34.73
Mangilao	50.88	50.89	92.86	99.23	82.14	97.45	100.00	95.48	83.09	83.09
Merizo	35.78	35.78	10.00	5.72	25.00	18.64	50.00	4.07	39.61	39.61
Mongmong-Toto-Maite	100.00	99.93	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Piti	94.97	94.98	100.00	100.00	100.00	100.00	100.00	100.00	95.19	95.19
Santa Rita	42.75	42.75	100.00	100.00	66.67	80.51	80.00	67.17	47.26	47.26
Sinajana	100.00	99.69	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Talofofo	49.27	49.28	87.50	91.39	100.00	100.00	100.00	93.15	99.07	99.07
Tamuning/ Tumon	100.00	99.98	100.00	100.00	100.00	100.00	100.00	100.00	100.00	10.00
Umatac	72.41	72.51	55.56	70.73	68.42	83.36	66.67	51.19	66.67	66.67
Yigo	83.57	83.57	72.73	95.42	96.97	98.88	83.33	77.10	83.02	83.02
Yona	88.40	88.38	83.33	99.31	100.00	100.00	100.00	98.72	93.59	93.59
Total	66.54	74.40	84.79	94.07	69.34	79.92	93.23	96.29	75.38	57.67

Table F-19 Vulnerability Analysis Results by Village: Total Affected by Severe Wind

Village	Area	Population	Essential Facilities		Major Utilities		Transportation Systems		GBS	
	Square Miles	No.	No.	Value ($)	No.	Value ($)	No.	Value ($)	No.	Value ($)
Agana Heights (Passan)	0.03	112	0	0	0	0	0	0	0	0
Agat	6.71	3,107	9	36,721,946	5	13,034,648	2	310,878	288	24,564,960
Asan	3.84	1,447	2	8,497,238	5	11,618,092	2	751,662	329	32,276,545
Barrigada	3.19	3,330	2	9,440,000	5	6,069,337	3	638,130	807	98,174,778
Chalan Pago-Ordot	0.11	133	2	1,417,238	1	5,862,031	0	0	50	4,495,500
Dededo	25.53	37,937	27	31,737,229	80	119,325,547	7	1,522,280	7339	117,051,178
Hagatna (Agana)	0.23	287	12	6,234,242	2	6,483,603	5	1,459,248	252	87,623,424
Inarajan	7.20	874	7	1,633,066	7	18,101,695	4	2,139,592	572	39,355,316
Mangilao	4.85	7,169	6	22,934,545	18	29,425,969	2	334,654	1502	222,521,300
Merizo	2.30	696	4	1,163,320	11	6,406,079	2	760,832	302	24,855,808
Mongmong-Toto-Maite	0.04	150	0	0	1	621,572	0	0	24	3,722,832
Piti	2.78	550	8	5,668,952	9	113,515,688	9	74,789,855	332	47,315,644
Santa Rita	4.98	1,845	0	0	6	16,812,755	1	66,247	715	56,301,960
Sinajana	0.00	0	0	0	0	0	0	0	0	0
Talofofo	8.43	1,445	4	1,966,678	5	16,735,634	1	43,863	491	44,859,233
Tamuning/ Tumon	0.87	3,004	25	312,625,666	5	27,249,700	4	1,212,866	271	111,835,738
Umatac	3.26	419	6	2,566,213	16	40,716,307	2	742,894	127	8,324,596
Yigo	33.10	19,002	11	12,811,622	33	55,674,951	6	1,189,513	4905	450,038,655
Yona	8.41	291	6	66,040,063	8	39,473,201	2	761,071	354	62,449,848
Total	115.86	84,197	131	521,458,018	217	527,126,809	52	86,723,585	18,660	1,435,767,315

Table F-20 Vulnerability Analysis Results by Village: Proportion Affected by Severe Wind

	Area	Population	Essential Facilities		Major Utilities		Transportation Systems		GBS	
Village	% of Sq. Miles	% of No.	% of No.	% of Value	% of No.	% of Value	% of No.	% of Value	% of No.	% of Value
Agana Heights (Passan)	2.91	2.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agat	63.18	63.19	45.00	84.23	55.56	54.24	100.00	93.71	20.99	20.99
Asan	67.72	67.71	40.00	88.31	50.00	50.00	66.67	73.76	45.69	45.69
Barrigada	37.53	37.52	8.33	33.13	29.41	51.77	20.00	8.39	28.49	28.49
Chalan Pago-Ordot	1.95	1.95	25.00	21.75	5.26	46.02	0.00	0.00	2.81	2.81
Dededo	84.40	84.41	77.14	78.14	83.33	95.37	38.89	36.79	74.21	7.42
Hagatna (Agana)	27.06	27.31	30.00	21.65	50.00	95.39	50.00	38.77	40.13	40.13
Inarajan	38.42	38.45	46.67	8.17	41.18	44.12	66.67	74.33	55.64	55.64
Mangilao	47.18	47.19	21.43	37.43	64.29	78.87	40.00	28.06	47.40	47.40
Merizo	37.58	37.62	40.00	28.04	68.75	48.03	100.00	98.07	44.81	44.81
Mongmong-Toto-Maite	2.20	2.20	0.00	0.00	14.29	13.83	0.00	0.00	1.82	1.82
Piti	37.82	37.83	42.11	46.66	69.23	41.14	81.82	99.27	40.94	40.94
Santa Rita	30.33	30.33	0.00	0.00	50.00	59.03	20.00	6.81	26.86	26.86
Sinajana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Talofofo	47.36	47.38	50.00	71.42	55.56	84.48	100.00	58.95	50.57	50.57
Tamuning/ Tumon	15.26	15.26	30.12	60.09	21.74	37.46	13.33	15.40	7.64	7.64
Umatac	53.53	53.58	66.67	82.35	84.21	88.27	66.67	51.19	48.11	48.11
Yigo	92.51	92.52	100.00	100.00	100.00	100.00	100.00	100.00	99.98	99.98
Yona	41.53	4.49	50.00	96.24	47.06	50.99	50.00	42.83	18.74	18.74
Total	55.22	52.84	36.90	57.55	59.94	59.57	39.10	76.95	46.57	23.46

Table F-21 Vulnerability Analysis Results by Village: Total Affected by Very High Landslide

Village	Area	Population	Essential Facilities		Major Utilities		Transportation Systems		GBS	
	Square Miles	No.	No.	Value ($)	No.	Value ($)	No.	Value ($)	No.	Value ($)
Agana Heights (Passan)	0.09	334	0	0	0	0	0	0	7	642,810
Agat	2.74	1,269	0	0	1	5,307,901	1	7,651	1	85,295
Asan	0.98	370	0	0	2	5,498,260	1	9,855	41	4,022,305
Barrigada	0.02	21	0	0	0	0	1	459	0	0
Chalan Pago-Ordot	0.19	230	0	0	0	0	1	72	5	449,550
Dededo	0.88	1,308	0	0	0	0	0	0	0	0
Hagatna (Agana)	0.05	63	0	0	1	122,970	1	1,242	45	15,647,040
Inarajan	14.37	1,743	4	6,121,072	5	11,186,879	5	2,809,430	255	17,544,765
Mangilao	0.54	799	1	237,238	0	0	0	0	6	888,900
Merizo	3.38	1,022	1	40,000	2	1,243,144	1	28,901	76	6,255,104
Mongmong-Toto-Maite	0.01	38	0	0	0	0	0	0	1	155,118
Piti	0.92	182	0	0	0	0	1	2,053	16	2,280,272
Santa Rita	1.85	686	0	0	0	0	0	0	8	629,952
Sinajana	0.05	146	0	0	1	190,359	0	0	7	702,240
Talofofo	12.91	2,213	3	674,926	3	10,806,161	1	15,007	38	3,471,794
Tamuning/ Tumon	0.20	691	2	474,476	1	24,763,412	1	5,333	40	16,507,120
Umatac	2.48	319	2	1,519,802	2	4,788,369	1	16,579	36	2,359,728
Yigo	2.21	1,269	0	0	0	0	0	0	1	91,751
Yona	2.78	890	0	0	0	0	1	6,815	20	3,528,240
Total	46.65	13,593	13	9,067,514	18	63,907,455	16	2,903,397	603	75,261,984

Table F-22 Vulnerability Analysis Results by Village: Proportion Affected by Very High Landslide

Village	Area	Population	Essential Facilities		Major Utilities		Transportation Systems		GBS	
	% of Sq. Miles	% of No.	% of No.	% of Value	% of No.	% of Value	% of No.	% of Value	% of No.	% of Value
Agana Heights (Passan)	8.74	8.77	0.00	0.00	0.00	0.00	0.00	0.00	0.77	0.77
Agat	25.80	25.81	0.00	0.00	11.11	22.09	50.00	2.31	0.07	0.07
Asan	17.28	17.31	0.00	0.00	20.00	23.66	33.33	0.97	5.69	5.69
Barrigada	0.24	0.24	0.00	0.00	0.00	0.00	6.67	0.01	0.00	0.00
Chalan Pago-Ordot	3.36	3.37	0.00	0.00	0.00	0.00	14.29	0.00	0.28	0.28
Dededo	2.91	2.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hagatna (Agana)	5.88	5.99	0.00	0.00	25.00	1.81	10.00	0.03	7.17	7.17
Inarajan	76.68	76.68	26.67	30.61	29.41	27.27	83.33	97.60	24.81	24.81
Mangilao	5.25	5.26	3.57	0.39	0.00	0.00	0.00	0.00	0.19	0.19
Merizo	55.23	55.24	10.00	0.96	12.50	9.32	50.00	3.73	11.28	11.28
Mongmong-Toto-Maite	0.55	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.08
Piti	12.52	12.52	0.00	0.00	0.00	0.00	9.09	0.00	1.97	1.97
Santa Rita	11.27	11.28	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.30
Sinajana	5.62	5.63	0.00	0.00	11.11	6.33	0.00	0.00	1.00	1.00
Talofofo	72.53	72.56	37.50	24.51	33.33	54.55	100.00	20.17	3.91	3.91
Tamuning/ Tumon	3.51	3.51	2.41	0.09	4.35	34.04	3.33	0.07	1.13	1.13
Umatac	40.72	40.79	22.22	48.77	10.53	10.38	33.33	1.14	13.64	13.64
Yigo	6.18	6.18	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02
Yona	13.73	13.73	0.00	0.00	0.00	0.00	25.00	0.38	1.06	1.06
Total	22.23	8.53	3.66	1.00	4.97	7.22	12.03	2.58	1.50	1.23

Table F-23 Vulnerability Analysis Results by Village: Total Affected by High Landslide

Village	Area	Population	Essential Facilities		Major Utilities		Transportation Systems		GBS	
	Square Miles	No.	No.	Value ($)	No.	Value ($)	No.	Value ($)	No.	Value ($)
Agana Heights (Passan)	0.00	0	0	0	0	0	0	0	0	0
Agat	2.25	1,042	3	2,784,249	4	6,310,191	1	31,704	286	24,394,370
Asan	0.00	0	0	0	0	0	0	0	0	0
Barrigada	0.00	0	0	0	0	0	0	0	0	0
Chalan Pago-Ordot	0.00	0	0	0	0	0	0	0	0	0
Dededo	0.00	0	0	0	0	0	0	0	0	0
Hagatna (Agana)	0.00	0	0	0	0	0	0	0	0	0
Inarajan	0.00	0	0	0	0	0	0	0	0	0
Mangilao	0.00	0	0	0	0	0	0	0	0	0
Merizo	2.45	741	8	3,871,440	11	10,229,982	2	736,105	537	44,197,248
Mongmong-Toto-Maite	0.00	0	0	0	0	0	0	0	0	0
Piti	00.0	0	0	0	0	0	0	0	0	0
Santa Rita	0.00	0	0	0	0	0	0	0	0	0
Sinajana	0.00	0	0	0	0	0	0	0	0	0
Talofofo	0.00	0	0	0	0	0	0	0	0	0
Tamuning/ Tumon	0.01	0	0	0	0	0	0	0	0	0
Umatac	3.61	464	7	1,596,278	17	41,337,879	3	1,434,607	228	14,944,944
Yigo	0.61	351	0	0	3	10,806,161	1	11,531	76	6,973,076
Yona	0.00	0	0	0	0	0	0	0	0	0
Total	8.93	2,598	18	8,251,967	35	68,684,213	7	2,213,947	1,127	90,509,638

Table F-24 Vulnerability Analysis Results by Village: Proportion Affected by High Landslide

Village	Area	Population	Essential Facilities		Major Utilities		Transportation Systems		GBS	
	% of Sq. Miles	% of No.	% of No.	% of Value	% of No.	% of Value	% of No.	% of Value	% of No.	% of Value
Agana Heights (Passan)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agat	21.19	21.19	15.00	6.39	44.44	26.26	50.00	9.56	20.85	20.85
Asan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Barrigada	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chalan Pago-Ordot	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dededo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hagatna (Agana)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Inarajan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mangilao	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Merizo	40.03	40.05	80.00	93.32	68.75	76.70	100.00	94.88	79.67	79.67
Mongmong-Toto-Maite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Piti	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Santa Rita	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sinajana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Talofofo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tamuning/ Tumon	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Umatac	59.28	59.34	77.78	51.23	89.47	89.62	100.00	98.86	86.36	86.36
Yigo	1.70	1.71	0.00	0.00	9.09	19.41	16.67	0.97	1.55	1.55
Yona	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	4.26	1.63	5.07	0.91	9.67	7.76	5.26	1.96	2.81	1.48

Table F-25 Vulnerability Analysis Results by Village: Total Affected by Tsunami Inundation

Village	Area	Population	Essential Facilities		Major Utilities		Transportation Systems		GBS	
	Square Miles	No.	No.	Value ($)	No.	Value ($)	No.	Value ($)	No.	Value ($)
Agana Heights (Passan)	0.002	8	0	0	0	0	1	277	0	0
Agat	0.70	325	9	37,642,213	4	7,726,747	2	298,743	553	47,168,135
Asan	0.23	87	3	9,243,541	1	621,572	3	966,321	142	13,930,910
Barrigada	0.00	0	0	0	0	0	0	0	0	0
Chalan Pago-Ordot	0.28	339	1	237,238	2	6,483,603	1	6,438	77	6,923,070
Dededo	0.16	238	0	0	0	0	0	0	0	0
Hagatna (Agana)	0.68	846	33	22,546,588	3	6,606,573	8	2,762,021	568	197,500,416
Inarajan	1.31	159	7	1,535,607	3	1,433,503	5	2,816,536	245	16,856,735
Mangilao	0.23	340	1	8,288,700	0	0	0	0	1	148,150
Merizo	0.82	248	2	688,844	11	6,837,292	2	769,670	434	35,719,936
Mongmong-Toto-Maite	0.27	1,012	0	0	0	0	0	0	29	4,498,422
Piti	1.96	388	13	9,548,203	11	245,835,548	11	75,318,444	369	52,588,773
Santa Rita	2.11	782	0	0	1	52,546	2	34,441	367	28,899,048
Sinajana	0.15	436	0	0	0	0	0	0	0	0
Talofofo	0.83	143	1	237,238	0	0	1	18,905	82	7,491,766
Tamuning/Tumon	0.64	2,210	19	82,269,731	7	4,940,338	10	2,716,620	333	137,421,774
Umatac	0.20	26	3	809,173	3	1,864,716	3	1,386,681	51	3,342,948
Yigo	0.33	190	0	0	0	0	0	0	0	0
Yona	0.84	269	1	237,238	0	0	3	1,413,343	19	3,351,828
Total	11.74	8,046	93	173,284,314	46	282,402,438	52	88,508,439	3,270	555,841,911

Table F-26 Vulnerability Analysis Results by Village: Proportion Affected by Tsunami Iunundation

Village	Area	Population	Essential Facilities		Major Utilities		Transportation Systems		GBS	
	% of Sq. Miles	% of No.	% of No.	% of Value	% of No.	% of Value	% of No.	% of Value	% of No.	% of Value
Agana Heights (Passan)	0.19	0.21	0.00	0.00	0.00	0.00	100.00	1.61	0.00	0.00
Agat	6.59	6.61	45.00	86.34	44.44	32.15	100.00	90.05	40.31	40.31
Asan	4.06	4.07	60.00	96.07	10.00	2.68	100.00	94.82	19.72	19.72
Barrigada	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chalan Pago-Ordot	4.96	4.97	12.50	3.64	10.53	50.90	14.29	0.37	4.32	4.32
Dededo	0.53	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hagatna (Agana)	80.00	80.49	82.50	78.31	75.00	97.20	80.00	73.39	90.45	90.45
Inarajan	6.99	7.00	46.67	7.68	17.65	3.49	83.33	97.84	23.83	23.83
Mangilao	2.24	2.24	3.57	13.53	0.00	0.00	0.00	0.00	0.03	0.03
Merizo	13.40	13.41	20.00	16.60	68.75	51.26	100.00	99.21	64.39	64.39
Mongmong-Toto-Maite	14.84	14.83	0.00	0.00	0.00	0.00	0.00	0.00	2.20	2.20
Piti	26.67	26.69	68.42	78.59	84.62	89.10	100.00	99.97	45.50	45.50
Santa Rita	12.85	12.85	0.00	0.00	8.33	0.18	40.00	3.54	13.79	13.79
Sinajana	16.85	16.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Talofofo	4.66	4.69	12.50	8.61	0.00	0.00	100.00	25.41	8.44	8.44
Tamuning/ Tumon	11.23	11.23	22.89	15.81	30.43	6.79	33.33	34.50	9.39	9.39
Umatac	3.28	3.32	33.33	25.97	15.79	4.04	100.00	95.56	19.32	19.32
Yigo	0.92	0.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Yona	4.15	4.15	8.33	0.35	0.00	0.00	75.00	79.54	1.01	1.01
Total	5.60	5.05	26.20	19.13	12.71	31.91	39.10	78.53	8.16	9.08

Table F-27 Vulnerability Analysis Results by Village: Total Affected by Very High Wildland Fire

Village	Area	Population	Essential Facilities		Major Utilities		Transportation Systems		GBS	
	Square Miles	No.	No.	Value ($)	No.	Value ($)	No.	Value ($)	No.	Value ($)
Agana Heights (Passan)	0.26	965	0	0	0	0	0	0	132	12,121,560
Agat	5.78	2,676	1	64,680	2	5,929,473	2	275,601	256	21,835,520
Asan	2.19	826	4	9,480,779	5	11,618,092	1	34,647	351	34,434,855
Barrigada	0.62	648	0	0	1	5,307,901	1	3,974	108	13,138,632
Chalan Pago-Ordot	3.02	3647	1	112,179	6	2,004,580	2	273,869	686	61,678,260
Dededo	14.34	21,309	5	4,709,417	31	30,346,601	2	287,153	2273	362,525,316
Hagatna (Agana)	0.18	224	0	0	1	190,359	1	5,979	36	12,517,632
Inarajan	5.88	714	3	1,733,541	4	1,192,649	3	1,427,751	240	16,512,720
Mangilao	2.50	3,695	2	1,417,238	3	4,375,564	2	269,541	233	34,518,950
Merizo	2.50	756	0	0	6	3,298,219	2	734,594	350	28,806,400
Mongmong-Toto-Maite	0.39	1,462	1	2,332,857	0	0	1	1,316	142	22,026,756
Piti	2.79	552	5	2,364,627	0	0	2	292,051	270	38,479,590
Santa Rita	5.57	2,064	0	0	5	12,126,426	4	555,331	730	57,483,120
Sinajana	0.66	1,916	5	2,516,329	7	1,763,726	2	259,429	416	41,733,120
Talofofo	8.03	1,377	0	0	0	0	1	5,375	109	9,958,567
Tamuning/Tumon	0.62	2,141	5	76,301,476	1	24,763,412	2	253,465	69	28,474,782
Umatac	2.29	294	1	237,238	7	16,685,139	2	723,218	88	5,768,224
Yigo	19.29	11,074	3	1,757,040	8	16,875,498	1	70,406	993	91,108,743
Yona	5.75	1,840	0	0	3	6,673,962	2	715,962	466	82,207,992
Total	82.66	58,180	36	103,027,401	90	143,151,601	33	6,189,662	7,948	975,330,739

Table F-28 Vulnerability Analysis Results by Village: Proportion Affected by Very High Wildland Fire

Village	Area	Population	Essential Facilities		Major Utilities		Transportation Systems		GBS	
	% Sq. Miles	% of No.	% of Value	% of Value	of No.	of Value	of No.	of Value	of No.	of Value
Agana Heights (Passan)	25.24	25.34	0.00	0.00	0.00	0.00	0.00	0.00	14.57	14.57
Agat	54.43	54.42	5.00	0.15	22.22	24.67	100.00	83.07	18.66	18.66
Asan	38.62	38.65	80.00	98.54	50.00	50.00	33.33	3.40	48.75	48.75
Barrigada	7.29	7.30	0.00	0.00	5.88	45.28	6.67	0.05	3.81	3.81
Chalan Pago-Ordot	53.45	53.46	12.50	1.72	31.58	15.74	28.57	15.69	38.50	38.50
Dededo	47.40	47.41	14.29	11.59	32.29	24.25	11.11	6.94	22.99	22.99
Hagatna (Agana)	21.18	21.31	0.00	0.00	25.00	2.80	10.00	0.16	5.73	5.73
Inarajan	31.38	31.41	20.00	8.67	23.53	2.91	50.00	49.60	23.35	23.35
Mangilao	24.32	24.32	7.14	2.31	10.71	11.73	40.00	22.60	7.35	7.35
Merizo	40.85	40.86	0.00	0.00	37.50	24.73	100.00	94.69	51.93	51.93
Mongmong-Toto-Maite	21.43	21.42	12.50	28.41	0.00	0.00	50.00	0.44	10.77	10.77
Piti	37.96	37.96	26.32	19.46	0.00	0.00	18.18	0.39	33.29	33.29
Santa Rita	33.92	33.93	0.00	0.00	41.67	42.57	80.00	57.08	27.42	27.42
Sinajana	74.16	73.92	71.43	76.86	77.78	58.66	100.00	99.24	59.51	59.51
Talofofo	45.11	45.15	0.00	0.00	0.00	0.00	100.00	7.22	11.23	11.23
Tamuning/ Tumon	10.88	10.88	6.02	14.66	4.35	34.04	6.67	3.22	1.95	1.95
Umatac	37.60	37.60	11.11	7.61	36.84	36.17	66.67	49.84	33.33	33.33
Yigo	53.91	53.92	27.27	13.71	24.24	30.31	16.67	5.92	20.24	20.24
Yona	28.40	28.40	0.00	0.00	17.65	8.62	50.00	40.29	24.67	24.67
Total	39.40	36.51	10.14	11.37	24.86	16.18	24.81	5.49	19.84	15.94

Table F-29 Vulnerability Analysis Results by Village: Total Affected by High Wildland Fire

Village	Area	Population	Essential Facilities		Major Utilities		Transportation Systems		GBS	
	Square Miles	No.	No.	Value ($)	No.	Value ($)	No.	Value ($)	No.	Value ($)
Agana Heights (Passan)	0.20	742	2	2,491,844	2	5,498,260	1	1,816	246	22,590,180
Agat	4.02	1,861	8	36,310,459	4	10,996,520	1	37,831	606	51,688,770
Asan	2.73	1,029	1	140,932	3	5,688,619	1	9,879	136	13,342,280
Barrigada	3.49	3,643	9	17,950,630	5	2,650,775	4	546,406	834	101,459,436
Chalan Pago-Ordot	1.11	1,341	4	3,348,646	3	1,002,290	1	13,042	415	37,312,650
Dededo	10.67	15,855	13	12,318,461	43	58,343,652	6	1,318,771	3816	608,621,472
Hagatna (Agana)	0.06	75	5	4,904,000	0	0	2	302,330	31	10,779,072
Inarajan	10.39	1,261	5	14,143,458	10	33,717,102	2	34,479	425	29,241,275
Mangilao	4.17	6,164	7	21,997,560	16	24,378,338	1	51,722	1043	154,520,450
Merizo	3.40	1,028	8	2,856,499	10	10,039,623	1	38,345	288	23,703,552
Mongmong-Toto-Maite	0.43	1,612	0	0	2	811,931	2	267,448	400	62,047,200
Piti	3.14	622	3	2,597,238	2	30,071,313	1	14,804	149	21,235,033
Santa Rita	6.61	2,449	2	983,541	2	5,498,260	1	75,061	1009	79,452,696
Sinajana	0.07	204	0	0	0	0	0	0	88	8,828,160
Talofofo	8.02	1,375	3	586,655	5	7,794,189	1	33,594	426	38,920,638
Tamuning/ Tumon	1.27	4,386	24	126,113,750	6	6,071,719	7	1,536,285	706	291,350,668
Umatac	3.68	473	8	2,878,842	10	23,511,636	2	725,571	175	11,470,900
Yigo	7.37	4,231	5	6,695,188	20	38,013,017	4	587,853	2150	197,264,650
Yona	11.47	3,670	2	1,394,743	6	53,430,452	2	310,352	718	126,663,816
Total	82.30	52,021	109	257,712,447	149	317,517,696	40	5,905,588	13,661	1,890,492,898

Table F-30 Vulnerability Analysis Results by Village: Proportion Affected by High Wildland Fire

	Area	Population	Essential Facilities		Major Utilities		Transportation Systems		GBS	
Village	**% of Sq. Miles**	**% of No.**	**% of No.**	**% of Value**	**% of No.**	**% of Value**	**% of No.**	**% of Value**	**% of No.**	**% of Value**
Agana Heights (Passan)	19.42	19.49	33.33	46.13	50.00	93.52	100.00	10.54	27.15	27.15
Agat	37.85	37.85	40.00	83.29	44.44	45.76	50.00	11.40	44.17	44.17
Asan	48.15	48.15	20.00	1.46	30.00	24.48	33.33	0.97	18.89	18.89
Barrigada	41.06	41.05	37.50	62.99	29.41	22.61	26.67	7.19	29.44	29.44
Chalan Pago-Ordot	19.65	19.66	50.00	51.39	15.79	7.87	14.29	0.75	23.29	23.29
Dededo	35.27	35.28	37.14	30.33	44.79	46.63	33.33	31.87	38.59	38.59
Hagatna (Agana)	7.06	7.14	12.50	17.03	0.00	0.00	20.00	8.03	4.94	4.94
Inarajan	55.44	55.48	33.33	70.72	58.82	82.18	33.33	1.20	41.34	41.34
Mangilao	40.56	40.58	25.00	35.90	57.14	65.34	20.00	4.34	32.91	32.91
Merizo	55.56	55.57	80.00	68.85	62.50	75.27	50.00	4.94	42.73	42.73
Mongmong-Toto-Maite	23.63	23.62	0.00	0.00	28.57	18.07	100.00	89.10	30.33	30.33
Piti	42.72	42.78	15.79	21.38	15.38	10.90	9.09	0.02	18.37	18.37
Santa Rita	40.26	40.25	28.57	3.74	16.67	19.30	20.00	7.72	37.90	37.90
Sinajana	7.87	7.87	0.00	0.00	0.00	0.00	0.00	0.00	12.59	12.59
Talofofo	45.06	45.08	37.50	21.30	55.56	39.34	100.00	45.15	43.87	43.87
Tamuning/ Tumon	22.28	22.28	28.92	24.24	26.09	8.35	23.33	19.51	19.90	19.90
Umatac	60.43	60.49	88.89	92.39	52.63	50.97	66.67	50.00	66.29	66.29
Yigo	20.60	20.60	45.45	52.26	60.61	68.28	66.67	49.42	43.82	43.82
Yona	56.64	56.64	16.67	2.03	35.29	69.03	50.00	17.47	38.01	38.01
Total	39.22	32.64	30.70	28.44	41.16	35.88	30.08	5.24	34.09	30.89

Appendix G
Plan Maintenance Documents

Annual Review Questionnaire

PLAN SECTION	QUESTIONS	YES	NO	COMMENTS
PLANNING PROCESS	Are there internal or external organizations and agencies that have been invaluable to the planning process or implementing a mitigation project and should be added to the HMAC?			
	Are there procedures (e.g., meeting announcements, plan updates) that can be done more efficiently?			
HAZARD PROFILES	Has a natural and/or human-caused disaster occurred in this reporting period?			
	Are there natural and/or human-caused hazards that have not been addressed in this HMP and should be?			
	Are additional maps or new hazard studies available? If so, what have they revealed?			
VULNERABILITY ANALYSIS	Are there any new essential facilities, lifeline utility systems, or transportation systems that need to be added to the current asset list?			
	Have there been changes in development patterns that could influence the effects of hazards or create additional risks?			
MITIGATION STRATEGY	Are there new or additional financial capabilities that are available for funding mitigation actions/projects?			
	Are the goals still applicable?			
	Do additional mitigation actions/projects need to be added to the Implementation Strategy?			
	Does the Implementation Strategy need to be reprioritized?			

QUARTERLY REPORT

FEMA HAZARD MITIGATION GRANT PROGRAM
SUBGRANTEE QUARTERLY REPORT FORM
FOR PERIOD _______ to _______

NAME
ORGANIZATION
ADDRESS
PHONE (S)
FAX
E-MAIL

PROJECT NAME:

PROJECT NUMBER:

1. *PROJECT START DATE:*

2. *PROJECT AMOUNT: $*

3. *ANTICIPATED COMPLETION DATE*

4. *TOTAL COST EXPENDED TO DATE* $ 0

5. *TOTAL FEDERAL REIMBURSEMENT RECEIVED* $ 0

6. *TOTAL FEDERAL REIMBURSEMENT PENDING* $ 0

7. *ANTICIPATED COST OVERRUN (UNDERRUN)*

8. *SUMMARY OF PROGRESS ON PROJECT* for the time frame [INSERT DATE] by task as listed on the state/local work agreement or contract. (Attach additional sheets if necessary.)

9. *PROBLEMS ENCOUNTERED:*

10. *ASSISTANCE NEEDED:*

11. *STATUS* (Please check pertinent information.):

PROJECT STATUS

(1) _____ Project on schedule
(2) _____ PROJECT SUSPENDED
(3) _____ Project delayed
(4) _____ Project cancelled
(5) _____ Project completed
(6) _____ Final

PROJECT COST STATUS

(1) ______ Cost unchanged
(2) ______ COST OVERRUN
(3) ______ Cost under-run

HAZARD MITIGATION GRANT PROGRAM

FINAL CLAIM

Upon completion of all work and payment of expenditures, please submit this sheet with your final Request for Reimbursement to:

Anthony M. Babauta

Governor's Authorized Representative / Governor's Chief of Staff

c/o **Leo Rustum J. Espia**, Guam Hazard Mitigation Officer

Guam Homeland Security/Office of Civil Defense

221-B Chalan Palasyo

Agana Heights, GU 96910

APPLICANT NAME: ______________________________

PHONE NUMBER: ______________________________

HAZARD MITIGATION PROJECT #: ______________________________

FEDERAL DISASTER #: ______________________________

SUBGRANTEE CERTIFICATION:

I HEREBY CERTIFY THAT, TO THE BEST OF MY KNOWLEDGE AND BELIEF, ALL WORK AND COSTS CLAIMED ARE ELIGIBLE IN ACCORDANCE WITH THE GRANT CONDITIONS; ALL WORK CLAIMED HAS BEEN COMPLETED; AND ALL COSTS CLAIMED HAVE BEEN PAID IN FULL.

SIGNED: ______________________________ **DATE:** ____________________

Authorized Applicant's Agent

TITLE OF AUTHORIZED AGENT: ______________________________

GOVERNMENT OF GUAM CERIFICATION:

I CERTIFY THAT ALL FUNDS WERE ACTUAL DIRECT EXPENDITURES IN ACCORDANCE WITH THE PROVISION OF THE FEMA-STATE AGREEMENT AND I RECOMMEND AN APPROVED AMOUNT OF $ ______________________________.

SIGNED: ________________________________ **DATE:** ___________________

GOVERNOR'S Authorized Representative

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